THE

JOURNAL OF GEOLOGY

APRIL–MAY, 1897

GLACIAL STUDIES IN GREENLAND. X.

The Bowdoin glacier.—The Bowdoin glacier is a lobe of the great inland ice-sheet which descends from the north into the head of the valley of Bowdoin Bay. It is joined on the east by ice pushing in through the intervals between a row of nunataks that lie on the plateau border. On the west it is confluent with the trunks of the Tuktoo and Sun glaciers which debouch into the broad flat valley at the head of McCormick Bay. This is only separated from the Bowdoin Bay valley by nunataks of which the Sierra and the Sentinel are the most conspicuous. These lie in the lower part of the common valley and have already been mentioned in connection with the Tuktoo glacier (see sketch map, p. 668, Vol. III). No very precise point can be fixed upon as the place of parting of the Bowdoin glacier from the main ice-cap, but it may fairly be regarded as having a length of six or eight miles. In its lower half it is joined on the east by the Obelisk glacier which comes in below the North nunatak and by the East Branch glacier which pushes in more directly from the east on the south side of the Obelisk nunatak. The East Branch glacier appears to terminate by lateral wastage almost at the point of joining the Bowdoin glacier and apparently never becomes really confluent with it. But the Obelisk glacier blends with and becomes a part of the Bowdoin glacier without being distinguished from it even by a medial moraine. The Bowdoin glacier in its lower part has a breadth

of about two miles. It is the master glacier of the vicinity both in respect to dimensions and activity.

The descent of its floor is apparently between 2000 and 3000 feet. This is accomplished by a somewhat steep fall from the

Fig. 64. Transverse view of Bowdoin glacier seen from the heights on the east looking northwesterly. The glacial movement is from right to left. The dark longitudinal line represents the sunken medial moraine. The undulations of the surface are fairly well indicated. The slope just beyond the crevassed area in the right foreground and between that area and the medial moraine inclines *backward*, *i. e.*, to the right, and a brook flows in that direction. The notable feature of the surface is the crevassing. The nunatak beyond the Bowdoin glacier on the right is the Sierra, that on the left the Sentinel. The Tuktoo glacier is seen between these and in the distance a glimpse of the Sun glacier is obtained. The ice-capped heights beyond are a part of the border of Prudhoe Land. Lieutenant Peary's first route across the ice-cap lay along these heights. Photograph by Professor Wm. Libbey, Jr.

upland to the valley, and then by a notable but unequal decline throughout its remaining course. The inequality of the decline is indicated not only by the undulation of its profile, but by intensive crevassing which distinguishes it from most of the valley glaciers of the vicinity. The crevassed condition is well shown in Fig. 64 and is worthy of thoughtful consideration when the relatively slight undulations and the relatively slow movement of the glacier are taken into consideration. Such pro-

nounced crevassing emphasizes the slight ductility of the ice. The failure of the ice to fill up the inequalities and form a continuously declining surface after the fashion of liquids is a further feature of interest. The undulations are so great as to

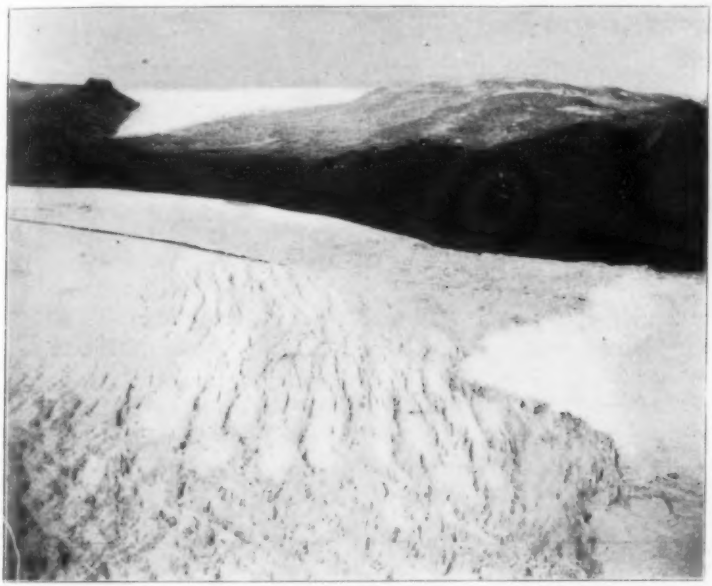


Fig. 65. The end of Bowdoin glacier. The head of Bowdoin Bay is seen at the right and the crevassed end of the glacier in the center and left. The dark line represents the medial moraine. The absence of other débris is notable. A portion of the ice-cap and the Mirror glacier are dimly seen in the distance. (The sky has been a little penciled.) The rounded embossment on the right is Bartlett Mountain, about 2600 feet high, the name being specifically applied to the frontal promontory. Sugar Loaf is seen at the left of Mirror glacier.

give rise to irregular surface drainage. In one instance at least, to which I was guided by Lieutenant Peary, the drainage is reversed. A considerable brook runs in a direction *opposite* to that of the motion of the glacier. It flows northward while the glacier flows southward. The northward

slope may be seen at the right hand of Fig. 64 a little this side of the medial moraine.

The Bowdoin glacier debouches at its lower extremity into the head of Bowdoin Bay and discharges icebergs of considerable dimensions, Fig. 65. This discharge seems to vary very greatly with the nature of the summer season. My observations happened to fall upon a season of relative quiescence. From the sixth to the twenty-third of August I occupied, through the kindness of Lieutenant Peary, a lodge overlooking the sea wall of the glacier and so near at hand as to be within easy hearing distance of any notable disruptive action but during this time I was not fortunate enough to witness the discharge of a single notable mass of ice, or even to hear it. A more substantial evidence of quiescence is found in the fact that within less than 200 yards of the extremity of the glacier on the east side there was an ice bridge spanning the lateral stream and connecting the glacier with a spur of rock. Lieutenant Peary informed me that the bridge had remained intact for two years and had been used as a means of communication with the glacier whose vertical face at other points rendered access difficult. It would be an error, however, to draw conclusions from these facts, for during the succeeding season the bridge was not only broken away but extensive discharges of icebergs took place along the sea face of the glacier. I presume that this unequal and somewhat spasmodic action represents the habit of the glacier. It seems probable that during a succession of severe seasons the motion of the ice is quite slight and the extremity of the glacier makes but little advance. But an exceptionally warm season following such a succession of severe ones, during which thickening and steepening of the gradient may have taken place, probably causes a notable thrusting forward of the glacial foot accompanied by corresponding iceberg discharge.

On its west side the Bowdoin glacier does not present an extensive vertical wall in accordance with the prevailing fashion of the region. In its upper part the glacier runs side by side

with the trunk of the Tuktoo glacier, as already observed. Below this it rubs hard against the Sierra and Sentinel nunataks and its activity is such as to prevent the development of the fossæ which often lie between nunataks and adjacent glaciers. Between the two nunataks named the glacier protrudes westward to meet the reciprocal eastward protuberance of the Tuktoo glacier, and the two jointly impound two small triangular lakes in the angles between themselves and the nunataks. Where the protuberances are opposite to each other their extremities are not vertical, though steep and somewhat stepped. This is perhaps due to the absence of the reflecting frontal plane which I have thought might be one of the factors in the development of the vertical faces. Each glacier standing opposite to the other covers the ground which would otherwise act as a reflecting surface.

On the east side of the Bowdoin glacier, however, there is the usual vertical face with its accompanying sharp triangular valley between the ice and the adjacent rock slope. This extends from the extremity of the glacier to the point of its junction with the East Branch glacier, a distance of perhaps three miles. At a few points spurs of rock close the valley. East Branch hill projects notably into the path of the glacier and not only closes the lateral valley but crowds the border of the ice out of its path. At these points of interruption the stream, which as usual runs between the glacier and the valley side, is forced to tunnel under the glacier. After a cold day or two, the water in the stream becomes low and the tunnels then afford a means of penetrating to limited distances beneath the ice, Fig. 66. The phenomena so disclosed, however, do not essentially differ from those seen to better advantage in the vertical sides. The amount of débris appears more scant because it is not concentrated by surface melting nor exaggerated by surface wash. In some instances where blocks of ice had recently fallen away from the roof, opportunity was given for the study of exceptionally fresh unweathered ice which had not been subjected to the sun's rays, except as they reached it through considerable depths of ice. Even here the ice is far from being

really compact and transparent. It varies from translucency in the more dense layers to nearly complete opacity in the more porous layers. This is an expression of lack of solidity and may be noted as specially instructive since the ice is here near

Fig. 66. Entrance to a tunnel under the side of Bowdoin glacier, looking downstream. The shoulder of rock which caused the undercutting of the stream is partially shown at the left. The peculiar arching of the beds is an interesting feature. Photograph by Professor Wm. Libbey, Jr.

the end of its career as a part of the glacier. As it was derived from the main ice-cap it may possibly have had as long a glacial history as often falls to such ice.

The stratification and the basal loading of the ice exhibited along the extended vertical face are much the same as in the glaciers previously described, but differ somewhat in the fact that the layers of ice are more warped and contorted, a result doubtless of the greater inequalities of the glacier's bed. Very notable dips of the glacial layers, both up stream and down stream, were frequently observed and sometimes reached large

angles, in one instance 70°. These dipping planes were sometimes marked by débris (though more commonly not) showing that they were genuine planes of acquired stratification. But the distortion often went far beyond mere changes of dip, how-

FIG. 67. Upthrusted and contorted ice layers on the east side of Bowdoin glacier just north of the East Branch hill. Lines of shearing, sharp flexures, localized belts of contortion and thrust, are among the notable features.

ever great or abrupt. It amounted to crumpling and even to faulting. A special instance is illustrated in Fig. 67.

The débris does not rise so high in the Bowdoin glacier as in some of the others already described. This fact is perhaps worthy of special note as this is a tongue of the great ice cap and has descended over an undulatory bottom nearly to the sea level. It is perhaps further worthy of note because this glacier discharges into the sea. The basal layers are not forced

upwards at their extremities to the same degree that was observed in some glaciers that have less free termination. A measurement of the upper limit of the débris-bearing layers at a point about two miles distant from the end of the glacier gave a height of only twenty-eight feet. Between this point and the extremity of the glacier the débris was usually confined to less heights, and at some points near the end it was not visible at all in the lateral face of the glacier. The amount of débris even within the limited range indicated was often relatively small and never very heavy. The accompanying photographs substantiate this. The bowlders of this glacier were usually more rounded than those previously described, and this rounding was of such a nature as to imply very considerable wear. The débris was composed wholly of crystalline rock, so far as observed, no admixture of clastic material being seen. The considerable rounding of the material, the small amount of débris and its low position at the base of the glacier are facts worthy of special note. They will be seen to have special significance when it is remembered that this is one of the larger (though not by any means the largest) tongues of the great ice-cap.

The rubbing of the glacier against shoulders of rock projecting from the side of the valley gave opportunity for observing some of the special phenomena of such situations. At one point the process of "plucking" was well indicated (though not actually observed) on the lee slope of a spur of gneissoid rock. Blocks ranging up to three or four feet in width and length and one or two feet in thickness had been detached in considerable numbers. The process involved much breaking and bruising with relatively little wear. Corners and angles were broken off and heavy bruise marks were observed both on the blocks and on the sides and edges of the cavities from which they had been removed. At some points considerable crushed rock was observed. On the other hand, systematic grooves and striæ were not abundant nor pronounced. The dynamic impression given was that of a forceful tearing out of blocks by the action of a

relatively rigid agency which did not press the blocks hard upon the lee slope after their removal.

At the point where the glacier grinds against the projecting side of the East Branch hill, the ice was notably crevassed, the fractures being most open at the side and gradually closing as they passed away toward the axis of the glacier. They were directed obliquely up stream according to the general law of lateral crevasses. Immediately against the obstructing projection the ice was broken up into numerous blocks and fragments and somewhat piled up against the side of the hill or tumbled back upon the upper surface of the glacier. The same thing occurs on the opposite side where the glacier rubs hard against the Sierra nunatak.

Just north of the point of forceful contact with the East Branch hill, a very interesting instance of contortion and upward thrust was observed. The accompanying figure (67) shows the nature of this better than any verbal description. It may be observed that near the base there are two quite pronounced lines which have the appearance of special shear planes. The contortion of the central belt in being forced obliquely upward is well displayed in the photograph. While the cause of the phenomena cannot be positively stated, it associated itself in my mind with the obtrusion of the projecting point of East Branch hill immediately below it. Whether this be the cause or not, the phenomena impress me as a clear case of forceful localized thrust with resulting foliation and shear planes.

At the point where the East Branch glacier joins the Bowdoin glacier, a large amount of débris had accumulated from a medial moraine derived from the Obelisk nunatak lying between the East Branch and the Obelisk glacier. The accumulated rubbish was the terminal dump of the medial moraine. There appeared to be much ice beneath this accumulated débris. It was obvious that both it and the extremity of the East Branch glacier had become essentially stationary. The more active Bowdoin glacier (or the Obelisk glacier, for the two are con-

tinuous) had forced itself over the edge of this débris. The result was the bending upwards of the edges of the layers of the Bowdoin glacier. Accompanying this there was a phenomenon which seemed at the time to be a clear and unequivocal expression of the shearing of these layers over each other, due to the resistance of the morainic material. Subsequent studies, as elsewhere remarked, led to some skepticism as to the validity of this interpretation. This point was not visited after the skeptical spirit arose, and hence I am only able to reproduce the observations and interpretations as they impressed themselves at the time. On the nearly vertical face of the glacier where it was most strained in being thrust over the morainic mass, there were as many as nine distinct projections of upper layers over under layers. The over-projection was sharp and definite and at once attracted the notice of my companion, Mr. E. B. Baldwin, who called my attention to it. The ground for skepticism regarding the interpretation of phenomena of this class is the presence of débris bands which may give rise to differential melting. There is no question that projections of a kind much like those here observed are due to such unequal melting. It seems to be demonstrable also that overthrust shearing takes place in this way. Each case must therefore be judged by itself. The limited amount of débris in this glacier encourages less skepticism regarding overthrust here than in some other cases. My notes state that pebbles and bowlders were sometimes lodged between these layers and that they appeared to have been pushed along the face of the layers in the shearing process, sometimes making grooves in the ice. Both notes and memory imply scantiness of débris between the layers. Unfortunately my photographs at this point were not a success. The overjutting of the layers ranged from a few inches to eighteen inches. They were most pronounced where the strain resulting from the obstruction would naturally be greatest and they died away in either direction. At another point somewhat farther on the phenomenon was repeated, but here there were but five chief planes of displacement in the vertical section. The maxi-

mum displacement of two adjacent layers, however, exceeded two feet. The adjacent faces appeared to be very distinctly fluted by the movement. Skepticism with reference to the interpretation of the fluting was subsequently raised on the

FIG. 68. Sunken medial moraine on the back of Bowdoin glacier; seen from a point near the moulin looking northerly. The ice motion is toward the foreground. The width of the moraine is about four rods and its depth below the general surface ten or fifteen feet. The stream's trench is shown at the left. It falls into the moulin at the lower right-hand corner. Glimpses of the main ice-cap are caught beyond the heights.

ground that it might perhaps be due to unequal melting by water trickling down the face of the ice, but, as elsewhere noted, in one instance at least, the débris in the junction plane was corrugated. It was noted here that a shearing plane was offset; that is, the shearing plane passed from the contact between two given planes to a similar contact between two planes below. The offset was downward and to the right or up-stream side. The overthrust was about six inches and the offsets, two of which were sketched, about eight inches.

The back of Bowdoin glacier is marked by an interesting medial moraine that takes its rise far up toward its junction with the main ice-cap, Fig. 68. I did not see its origin, but Lieutenant Peary informed me that it came to the surface from beneath the ice at a point north of the north nunatak, but south of the descent of the ice from the main plateau. On account of this he could not be certain whether it was derived from a nunatak that lies still farther north on the border of the main plateau, or from some concealed embossment. Undoubtedly the material was picked up from a prominence on or near the edge of the plateau. The débris is so thinly spread that it catches the sunlight and by conversion and conduction makes its heat available to the ice. As a result the moraine is sunken ten or fifteen feet below the surrounding surface. In breadth and form it is not unlike a depressed street strewn with coarse débris. On one side of it a stream has cut a notable trench through which a considerable body of water flowed during the warm days of August. Fig. 68 illustrates the moraine and its depressed condition, as also the channel on the west side. The latter terminates in a moulin at the right-hand lower corner of the illustration. The moraine is also illustrated in the general transverse view of the glacier shown in Fig. 64.

T. C. CHAMBERLIN.

ITALIAN PETROLOGICAL STUDIES.

IV. THE ROCCA MONFINA REGION.

THE volcano of Rocca Monfina, was long celebrated as one of the classical examples brought forward in favor of von Buch's hypothesis of Craters of Elevation. Its historical interest is equaled by its interest from a petrological point of view, since, apart from the character of the rocks of which it is built up, their order of succession forms an exception to that met with elsewhere among the Italian volcanoes. My visit to the locality was extremely brief and was confined to a trip from Teano on the eastern border, past the central mass of Mte. Sta. Croce to Conca, with one or two short excursions. I must therefore rely for most of my knowledge of the volcano on the work of others — a resource which in this case is somewhat meager.

Rocca Monfina has been in fact one of the most neglected of Italian volcanoes. The early works, chief among which are those of Abich[1] (who gives views and a map), Daubeny[2] and Pilla[3] are devoted to an exposition of their views in favor of von Buch's theory and the examination of the volcano from this standpoint. They are therefore chiefly of historical value, though Abich gives some descriptions of the rocks. Vom Rath[4] devotes a few pages of Part IV of his "Italian Fragments" to a description and analyses of two of the rocks, which we shall have occasion to notice later. A few others are briefly described by J. Roth,[5] and Bucca's descriptions are quoted by Rosenbusch. The only modern writers who deal at all fully with the region

[1] ABICH, Vulk. Ersch. der Erde. Braunschweig, 1841.
[2] DAUBENY, Volcanoes, London, 1848. 174.
[3] PILLA, cf. Neu. Jahrb. 1845, 843, and references in Moderni.
[4] VOM RATH, Zeit. d. d. geol. Ges. 243, 1873.
[5] ROTH, Geologie, II, 245, 275, 354.

are Bucca[1] and Moderni.[2] The former gives petrographical descriptions of the rocks collected by Moderni; and the latter describes the region from a geological point of view, giving a quite detailed geological map on a scale of 1:100,000. Deecke[3] also touches upon the tuffs of the region in an article on the tuffs of Campania.

Topography.— The volcano of Rocca Monfina lies about 70 kilometers northwest of Naples, west of the main railroad line from Naples to Rome. In the center is the trachy-andesitic dome of Mte. Sta. Croce, 1005 meters above sea level, with the smaller similar dome of Mte. Lattani (847 meters) adjoining it to the northeast. These are steep well-wooded hills, made up of solid masses of eruptive rock, with no tuffs nor signs of separate lava flows. At the eastern foot of Mte. Sta. Croce is the small town of Rocca Monfina, and extending around the two domes, especially to the east and south, is the plain of the same name. This plain (from 500 to 650 meters above sea level) is bounded by the remains of a large crater ring, which is almost circular in form and with a diameter of about 6 kilometers. At the west and south the ridge, which is called Mte. Cortinelli, is quite high and sharp, reaching its maximum elevation on the west at Mte. la Frascara (926 meters). Its inner slope is very steep, while on the exterior it is very gentle, between 6° and 10°. On the northeast and southeast the plain is bounded by a series of hills which become less high as they are farther from the center. This part of the crater ring has suffered much from erosion, being furrowed by many deep radiating ravines.

In regard to the age of the volcano Moderni says that little can be stated positively, except that at various places volcanic material is seen resting on Middle Eocene beds. Deecke notes the superposition of Rocca Monfina tuffs on the gray Campanian tuffs. It is probable that like the other volcanoes previously

[1] Bucca, Boll. Com. Geol. Ital., 1886, 245.

[2] Moderni, Boll. Com. Geol. Ital., 1887, 74.

[3] Deecke, Neu. Jahrb. 1893, I, 62, 65.

described the eruptions date from the Pliocene. The date of extinction of the volcano is likewise uncertain, though probably quite recent. Some lead objects and ancient buildings, with frescoes have been found beneath the tuffs, and the date 269 B.C. has been proposed for this period— on what authority I am unable to state as Moderni's reference is inaccessible to me. Moderni however, taking into consideration the silence of the ancient writers, the want of exact data, and the liability of objects being buried by the easily transported tuff, rejects this view and leaves the question an open one.[1] The hot springs of Sujo[2] are the last symptoms of volcanic activity manifest at the present day.

Petrography.— Moderni recognizes three phases of activity in the volcano, distinguished by different products of eruption: (1) the leucitic, the oldest, which is subdivided into two sub-phases characterized by leucitites and leucite-tephrites; (2) the trachytic; (3) the basaltic, which is the youngest. As my own observations were not extended enough to enable me to judge of this point for myself I shall accept Moderni's views. The volcano is thus seen to form a notable exception to most of the composite volcanoes of Italy— the order of succession of the leucitic and non-leucitic rocks being reversed. Before entering on the petrographical descriptions it will be as well to give a brief résumé of Moderni's work.

While it is difficult to unravel certain portions of the history of the volcano one fact is certain, that the first lava erupted was leucitite. This is shown by the fact that it is found beneath all the others. The flows of this rock are the greatest in amount of any of those of the region. They form a large part of the ridge of Mte. Cortinelli, with flows at many points elsewhere round the crater ring which it is unnecessary to enumerate here. There are certain eruptive centers on the flanks of the volcano which gave vent to this type of rock, but the vast flows of the western half seem to have been poured out of the central crater. Lying above

[1] This is also the conclusion to which Daubeny comes in the second edition of his Volcanoes, London, 1848, p. 178.

[2] JOHNSTON-LAVIS, South Italian Volcanoes, Naples, 1891, 73.

the leucitites, and covering almost all the western part of the cone, are leucite-tephrites, whose amount, while great, is not equal to that of the leucitite. These also appear as small flows in the northern and eastern parts. Belonging to this period are certain tuffs, the most extensive of these being a gray lithoidal tuff which covers the flanks and extends for a great distance to the north, east, and south of the volcano. Moderni estimates that the volcano at the close of this period had an altitude of nearly 3000 meters.

The second or trachytic phase was inaugurated by the blowing out of the large central cavity, which involved the destruction of the greater part of the northern and eastern wall. It was during the first part of this phase that the double dome of Mti. Sta. Croce and Lattani was formed. These form, as already observed, a homogeneous compact mass, and are a good example of a "domal" eruption of a pasty magma which was not sufficiently fluid to flow to any great distance. The material of this eruption was of a trachy-andesite approaching the vulsinites already described, while the other eruptions of this period were of a more acid and more nearly trachytic rock and were all flank eruptions. While stating that it is impossible to decide definitely whether the central domal or the flank eruption took place first, Moderni thinks it more probable that the former was the earlier. He bases this conclusion on the ground that the large domal eruption choked up the main central vent, so that any further ejection of volcanic material had to take place through the flanks of the volcano. It is needless to mention in detail the various trachytic flows, which moreover are not nearly as large in amount as the flows of the first phase. With the trachyte there was also erupted a small quantity of leucitic rock. Several areas of trachytic tuffs also belong to this phase.

The third and last phase of activity was characterized by the eruption of basaltic rocks in which leucite is entirely wanting. These eruptions were of small amount, the quantity of basalt being even less than that of the trachytes. They formed a number of small parasitic cones, the lava poured out being often

scoriaceous. Most of these small cones were formed on the outer flanks of the volcano, but three are found in the interior, one being in the valley of Pratolungo between Mte. Sta. Croce and Mte. Lattani. The tuffs belonging to this phase are few and of small amount. That the eruption of the "basalts" was posterior to those of the leucitites and trachytes is made evident by several facts. The small cones formed by them are the best preserved of all, in many cases quite intact and covered with lapilli and bombs and with their lava flows quite bare. At Sipicciano on the northwest flank of Mte. Cortinelli a basaltic flow covers the leucitites and leucite-tephrites; while in the central eruption at Pratolungo the flow of "basalt" is seen to be superposed on the trachy-andesite of Mte. Lattani.

Leucitite.—This is represented by only one specimen in my collection, from a flow below Preta, on the outer northern side of the volcano. This shows a very compact, fine grained, dark gray groundmass, through which are scattered many small but quite glassy leucites, with rare specks of augite. In thin sections these large leucites are seen to be perfectly clear, and they show very weak double refraction for such large fresh crystals. Over the greater part of their area they carry almost no inclusions, but at the edge of almost all is a very narrow peripheral line of small augite microlites, which in turn is surrounded by a narrow mantle of leucite. This shades into the groundmass, and is quite analogous to the alkali feldspar mantles so frequently noticed in the preceding papers. Apart from the leucites only rare light green augite phenocrysts are seen, which also carry no inclusions.

The groundmass is fine grained and composed essentially of small leucites with interestitial greenish gray augite prisms and anhedra and a little magnetite. These small crystals are imbedded in a colorless isotropic substance. It is possible that this is glass, but, judging from the leucitic mantles around the leucite phenocrysts and from the fact that there is no difference in refractive index between this base and the small leucites, it seems probable that it is leucite. It would thus correspond to the nepheline base of certain phonolites and other nepheline rocks, such

as have been noticed previously. A very few flakes of alkali feldspar are also met with.

Leucite-tephrite.—One specimen of this rock was collected at Mte. San. Antonio (707 meters high), which forms one of the girdle of hills around the plain and lies due north of Mte. Lattani. The rock shows a fine grained gray groundmass in which, with the exception of very rare augites, the only phenocrysts visible are leucites. These are extremely abundant, making up a large portion of the rock. They are apparently fresh, with a waxy luster; the smaller ones pale gray, while the larger show a core of dark gray and an outer shell of light gray. This rock is extremely tough. In thin sections the large leucites are very prominent. They are clear and show strong double refraction. Inclusions are abundant, of small crystals of anorthite and green augite. They include also many small slender needles of diopside, minute grains of magnetite and spots of glass, which are very commonly clustered toward the center of the crystal, thus accounting for the dark gray cores. Beside the leucites only one or two dark green augite phenocrysts were seen in the slides. The groundmass is composed largely of irregularly shaped greenish yellow augite grains, a few small leucites, considerable magnetite, many small crystals of a plagioclase which is shown by its extinction angles to be anorthite, and some small flakes and laths of alkali feldspar. A little residual glass is also present.

A peculiar leucite-tephrite is that, from what appeared to be a small flow on the road to Conca, below Orchi. It is very dark gray and fine grained, but rather rough in texture. A few phenocrysts of augite and leucite are visible. Under the microscope it shows the doleritic structure which is so common to the Italian leucite-tephrites. None of the phenocrysts were met with in the single section which was made of this rock. In the groundmass stout columnar, pale green augites are very abundant, the largest showing cores of darker green; while these are clear and contain few inclusions (of magnetite and glass), their outlines are very irregular, most of the prisms showing deep embayments due to corrosion. A little brown barkevikitic amphibole and a few

flakes of brown biotite are also present. There are also numerous grains of magnetite and a few apatite needles.

Leucite is present in abundance, but shows an unusual habit. While often in the form of small, rounded or trapezohedral crystals, it generally occurs in irregularly shaped masses, occasionally showing crystal planes here and there, or with small, definitely shaped crystals attached to the larger mass. These leucites are extremely clear, and show a remarkably faint double refraction. Indeed so faint is the action of these leucites on polarized light, that in most of the crystals recourse must be had to the quartz wedge before any such action can be perceived, a proceeding not often necessary in the Italian leucitic rocks.

Later than the leucites, and often enclosing them micropoikilitically,[1] are flakes and large patches of a plagioclase with generally well developed twinning lamellæ, whose high symmetrical extinction angles refer it to anorthite. There are also some patches of a feldspar, which, though not showing any signs of twinning, may also be referred to anorthite on the ground of the equality of its refraction with that of the striated anorthite. There is also considerable colorless base, which, while in general isotropic, shows in places a very faint double refraction. Since treatment of the powdered rock with acids produces abundant gelatinous silica, this base may be regarded as nepheline, or at least as a glass corresponding to nepheline in chemical composition. An analysis of this rock made for me by Dr. A. Röling of Leipzig is here inserted:

SiO_2	47.40
Al_2O_3	19.84
Fe_2O_3	2.72
FeO	4.40
MgO	4.23
CaO	9.88
Na_2O	2.93
K_2O	5.91
H_2O	1.66
TiO_2	0.30
	99.27

[1] The marked difference in refractive indices between the leucite and anorthite serve to bring the structure out very nicely in ordinary light, while the dark spots of

A leucite-tephrite from Mte. San Antonio is described by vom Rath,[1] which seems to be more like the Conca tephrite than the other just described. Megascopically only few phenocrysts of augite, leucite and feldspar are visible, while under the microscope the groundmass resembles that of many leucitites already described. Sanidine phenocrysts are few, but smaller ones of plagioclose are abundant. Vom Rath's analysis is inserted here:

SiO^2	58.48
Al_2O_3	19.56
FeO	4.99
MgO	0.53
CaO	2.60
Na_2O	3.14
K_2O	10.47
H_2O	0.24
	100.01

Leucite-trachyte.—The occurrences of this rock which I observed seemed to belong to the second (trachytic) phase of the volcano, though on this point I cannot speak with certainty. My specimens may be referred to two different varieties, an augitic and a biotitic. To the former belongs the rock of a well marked flow at Acqua Rotta, about a kilometer and a half northwest of Teano. The groundmass of this is very compact and fine grained, and of a dark gray color. Leucite phenocrysts are not abundant, but many small black augites and a few flakes of biotite are visible. Under the microscope a few large leucite sections met with are clear, with quite strong double refraction, and show few inclusions. The pale green augite phenocrysts are clear, carry inclusions of magnetite, especially toward the edges, and generally show corroded outlines. The biotites present are all altered to an almost opaque, finely granular mass of augite and magnetite, generally to such an extent that but little of the original mineral remains. The groundmass resembles that of many leucitites, being composed largely of small round leucites,

leucite show out with striking clearness against the background of bright anorthite between crossed nicols.

[1] VOM RATH, op. cit. 243.

with interstitial prisms of green augite, many magnetite grains, and flakes and laths of alkali feldspar. Some larger crystals of anorthite are also seen. No glass seems to be present.

To the biotite-leucite-trachytes belong specimens from Tuoro west of Acqua Rotta, and from below Orchi on the northern flank of the volcano. Their groundmass is lighter gray than that of the preceding, small leucite and augite phenocrysts are not very common, but there is an abundance of flakes of biotite of a dark brown color and bronzy luster. In thin section they very much resemble the preceding. Augite phenocrysts are, however, rare, their place being taken by biotite. In the rock from Tuoro its color is of a deep orange red, while in that from Orchi it is much paler. It is much altered at the edges to the usual fine grained aggregate. In the groundmass of the former the alkali feldspar is in the form of laths, in the latter it is rather in the form of flakes and interstitial cement. Some basic plagioclase is present, but in small amount.

A rock which occupies a position between the above and the following group is represented by a specimen also from below Orchi. Megascopically this closely resembles the other, the only important difference being that here leucite phenocrysts are entirely wanting, and replaced by glassy sanidines. There is also considerable augite along with the biotite. The rock in thin section resembles more one of the vulsinites to be described presently than a leucite-trachyte. The sanidine phenocrysts are rarely met with. Large greenish gray augites are not uncommon, which carry inclusions of brown glass and magnetite and are somewhat corroded. The biotites are all profoundly altered, usually so much so that the crystal is almost completely disintegrated. The groundmass is made up of flakes and laths of an alkali feldspar, with a considerable number of laths and basic plagioclase which are usually surrounded by mantles of orientated alkali feldspar. Small grayish green irregularly shaped and corroded augite crystals with magnetite grains are common. There are also present many small round spots of leucite, recognized by their characteristic inclusions and by their analogies

with other occurrences. A scanty glassy base is also present. No nepheline was detected in any of the above rocks.

Biotite-vulsinite.—In the descriptions of the volcanic centers which form the subject of the preceding papers we have had occasion to examine certain members of a group of effusive rocks which, both chemically and mineralogically, stand in a position intermediate between the trachytes and the andesites. The Rocca Monfina region resembles the others in furnishing—and very prominently—members of this group. We find here in fact effusive rocks showing the mineral combination of alkali feldspar and basic plagioclase, which approximate closely to the ciminite of the Viterbo region in chemical composition. Mineralogically, however, they come closer to vulsinite of Lake Bolsena, no olivine being present, but augite and especially *biotite* being abundant representatives of the ferromagnesian minerals. So much indeed do they resemble vulsinite that they were considered at first to belong to this group, forming a species which would be called a biotite-vulsinite, as was briefly noticed in the paper on the Bolsena Region.[1] A chemical analysis, however, which I completed after the printing of that article and which will be found on page 252, shows that this determination is not quite correct. It will be seen that the silica is notably lower than in the vulsinites, and furthermore that lime, magnesia and iron are very much higher, while the alkalies are considerably lower. Comparison with the analysis of the Viterbo ciminite (which is inserted for convenience) will show that the trio are *chemically* almost identical. We have then a rock which is chemically a ciminite and mineralogically, a biotite-vulsinite.

In regard to the name by which they should be called there may be some doubt. From a mineralogical standpoint they are obviously not ciminite, nor chemically can they strictly be called vulsinite. Since, however, in the schemes of classification in general use at the present time, the mineralogical composition takes precedence over the chemical, and bearing in mind the unadvisability of adding new names to the already

[1] Jour. of Geol., IV, pp. 551–553, 1896.

overburdened nomenclature, I shall designate these rocks as *biotite-vulsinite*.

The most important occurrence of biotite-vulsinite is that of Mti. Sta. Croce and Lattani, which are, as far as can be seen, entirely formed by a domal eruption of the rock just noted. This was called "trachy-dolerite" by Abich,[1] he considering it a link intermediate between trachyte and dolerite, while Pilla and von Rath consider it a trachyte. Bucca calls it an augite-andesite, and refers the greater part, if not all, of the feldspar to plagioclase. Otherwise his description agrees closely with mine.

The Santa Croce rock is trachytic in appearance, having a fine grained, but not very compact, light gray groundmass of a slightly reddish tone. Through this are scattered very many small, dark brown flakes of biotite, some small augites, and a few small feldspars. The groundmass of the Mte. Lattani rock is rather darker and of a bluish gray color, more compact, biotite flakes are less abundant, and feldspars more common. My specimen of this latter is not quite fresh. In thin section the feldspar phenocrysts are quite common. They consist of an alkali feldspar, apparently a soda-orthoclase, and a larger number of plagioclase, which is shown by its extinction angles to have the composition Ab_2An_3. These are well shaped, but contain many inclusions of glass with small opaque grains and augite microlites. The biotites are of a greenish brown color, quite fresh in the interior, but surrounded by a thin alteration border of fine augite and magnetite grains. The large, irregularly shaped augites are pale green. The groundmass is trachytic in character and shows well-marked flow structure. There is an abundance of small laths, chiefly of alkali feldspar, with some of plagioclase. Magnetite grains and small diopside microlites are present in abundance, and there is a residue base of alkali feldspar.

The rock of Mte. Lattani closely resembles the above, though there are certain differences, the rather more abundant feldspar-phenocrysts are identical, as is also the augite. The biotites are,

[1] ABICH, Vulk. Ersch., Brunswich, 1841, 100.

however, all completely, or almost completely, altered, the product being rather coarsely granular. The grains are very slightly coherent with one another, and show in a very striking way the distribution of such augite and magnetite grains through the groundmass of certain rocks, as has been already pointed out.[1] The groundmass is holocrystalline, and composed largely of flakes of alkali feldspar, with few laths. The augite and magnetite grains resulting from the disintegration of the biotite are very abundant. Bucca refers this Mte. Lattani rock to the trachytes, though, as will presently be seen, he is struck by their andeistic character.

An analysis of the rock of Mte. Santa Croce (I) made by myself is given below, II being an analysis of the same occurrence by vom Rath,[2] and III being an analysis of the ciminite of Fontenu Fiesole, near Viterbo,[3] inserted for convenient comparison.

Abich (p. 114) gives the silica percentage as 57.41 and the specific gravity as 2.79.

	I	II	III
SiO_2	55.69	55.08	55.44
Al_2O_3	19.08	17.25	18.60
Fe_2O_3	4.07	—	2.09
FeO	3.26	9.33	4.48
MgO	3.41	2.77	4.75
CaO	6.87	7.34	6.70
Na_2O	2.89	1.86	1.79
K_2O	4.41	5.32	6.63
H_2O	0.17	0.17	0.25
TiO_2	tr.	—	0.16
P_2O_5	—	—	tr.
MnO	tr.	—	—
	99.85	99.12	100.75
Sp. gr.		2.713	

Belonging to the same group is a specimen from a flow met with in the valley east of Casi, to the west of Teano. This is a

[1] Cf. Jour. of Geol., IV, 270, 1896.

[2] Vom Rath, Zeit. d. d. geol. Ges., XXV, 245, 1873.

[3] H. S. Washington, Jour. of Geol., IV, ——, 1896.

medium gray compact rock showing small biotite, augite, and feldspar phenocrysts. In thin sections the phenocrysts of alkali feldspar and basic plagioclase are present in about equal amounts. They contain many glass inclusions. The biotite phenocrysts are all deeply altered, and a few large augites met with show no noteworthy features. The groundmass is trachytic and composed of flakes and laths of alkali feldspar, with laths of plagioclase, diopside needles, and magnetite grains. There is little or no glass present.

Rocks which represent transitional forms between the above and true trachytes are found in specimens from the ravine at Molino di Casa Fredda, from a flow northwest of Tuoro, near Teano, and from a loose block in the valley of Casi. They resemble the rocks already described, but plagioclase is much less abundant, and in some almost entirely wanting. The groundmass of the Casi rock is much darker and finer grained than in the other cases; feldspar phenocrysts are abundant, but few of ferromagnesian minerals are seen. Some good examples of microperthite seen in it indicate that the alkali feldspar contains considerable soda. In the specimen from Tuoro a noteworthy feature is the presence in one slide of a single, large, well-shaped crystal of colorless diallage, showing its characteristic dusty inclusions and parting parallel to the orthopinacoid These, as well as other rocks similar to these, are all described by Bucca under the head of trachytes, his descriptions agreeing very closely with the characters of my specimens. He closes, however, with the significant remark (p. 257) that they "approach so closely to the andesites that I was tempted several times to refer them to these."

Trachyte.—A rock from a small quarry on the road to Conca, on the northern outer flank of the volcano, belongs to the trachytes proper rather than the vulsinites. It is the same as a rock described by Bucca (p. 255), whose description agrees very well with the characters of my specimens. The main mass of the rock is compact and light gray, showing few phenocrysts of augite and feldspar. Scattered through this are rounded

black masses, which often attain diameters of five centimeters. These are coarsely crystalline and not very compact, with miarolitic and vesicular cavities. Under the microscope the only phenocrysts visible are of pyroxene. These are usually well formed, but occasionally quite fragmentary. The interior consists of a colorless diopside, which is uniformly surrounded by a rather narrow border of yellowish green non-pleochroic augite. The substance of this border corresponds exactly with that of the small groundmass augites, so that it is due to the same late period of growth to which they belong. The large augites are hence a good instance of the growth and enlargement of crystals brought up from below by the late accretion of isomorphous substance of somewhat different composition. Apart from the not very abundant small augites and magnetites, the groundmass is made up of feldspar and some residual glass. The feldspar forms laths with somewhat ragged edges, and they, with the augites, show well-marked flow structure. The greater part of these laths are of orthoclase, or at least an alkali feldspar; only very few showing twinning striations and extinctions which would refer them to plagioclase. No suitable sections of these latter were found by which their approximate composition could be determined, though I am inclined to think that they belong to the middle of the plagioclase series rather than to the basic end. The powdered rock, on treatment with acids, furnishes abundant gelatinous silica, which probably comes from the glass base. The dark spots referred to above are seen under the microscope to be holocrystalline, and composed of a few large diopsides with augite borders and very many smaller prismatic augites lying in a cement of orthoclase or alkali feldspar. The line of junction with the surrounding rock is quite sharp. They are true segregations and are to be classed with the *enclaves homœogènes* of Lacroix.[1]

Bucca also mentions briefly the rock of Mte. Ofelio, near Sessa, on the southwest flank of the volcano, as a true trachyte. It seems to be much decomposed.

[1] LACROIX, Enclaves des Roches, Macon, 1893, 8.

Basalt.—Of the rocks of this class described by Moderni and Bucca, I was unfortunately unable to obtain specimens. This is the more to be regretted, inasmuch as the feldspar basalts are only sparingly represented along the main line of Italian volcanoes, and at Rocco Monfina they are, according to Moderni, the last product of volcanic activity. Bucca describes a number of them, and his observations may be summarized here so as to complete as far as is possible, the petrographical description of the region.

The basalts of the region are apparently quite feldspathic, and are quite free from leucite or nepheline. In the majority of cases they are olivine-bearing, this mineral being generally phenocrystic, and seldom forming part of the groundmass. It is usually somewhat altered, especially on the borders, to a dark red substance. A few specimens are free from olivine and approach the augite-andesites, but are classed by Bucca with the basalts on account of their basic character. These last are of a light gray color, while the olivine basalts are dark. Augite is abundant, of a slightly bluish green, and not pleochroic. In two specimens a dark reddish brown biotite is present, which is for the most part largely altered to the usual augite-magnetite aggregate. The plane of the optic axes is perpendicular to the plane of symmetry. Feldspar which is referred to plagioclase rarely appears as phenocrysts, but is abundant as laths in the groundmass. Its optical characters are not noted, so that we are unable to judge of its place in the series. Small magnetite grains are abundant and a colorless glass base is usually present.

Although Bucca constantly refers to the feldspar as plagioclase, yet he does not mention twinning lamellæ, and indeed treats it in a rather cursory way. Certain facts, indeed, incline me to the belief that there is some, if not quite a good deal, of orthoclase in the rock. In the first place all the rocks which I have examined from this and the other volcanic centers are eminently rich in potash, even the phonolite of Viterbo containing 9.14 per cent. of it. It would then be quite anomalous to find here such a rock as a normal basalt containing a mini-

mum amount of this alkali. If the feldspar is all plagioclase, as Bucca's description would indicate, there would be no mineral capable of taking up any notable amount of potash, as its percentage in biotite is never over 10., and the amount of this mineral in these rocks is small.

Furthermore we find at Radicofani, which is on the same main line, "basalts" containing very considerable orthoclase along with the plagioclase, and showing in one instance: $SiO_2 = 55.13$; $K_2O = 2.43$, and $Na_2O = 2.07$. Again Abich (*op. cit.* page 114) gives the silica percentage of the "basalt" from the foot of Santa Croce as 54.62, and classes it as a trachy-dolerite, though a rather basic one resembling the dolerites, while the rock of Monte Santa Croce is more acid and like the trachytes. It seems then very probable that these "basalts" of Rocca Monfina are in reality not normal plagioclase basalts, but rather approach the ciminites in composition both mineralogically and chemically.

HENRY S. WASHINGTON.

ARE THE BOWLDER CLAYS OF THE GREAT PLAINS MARINE?

SEVERAL trains of evidence show that the western plains, as well as the Cordilleran region, have been affected by great changes in elevation relatively to the sea level and to that of the eastern parts of the continent in later Tertiary and Pleistocene times. Facts bearing upon these changes have been detailed by the writer in previous papers and more particularly in those entitled respectively "Later physiographical geology of the Rocky Mountain region," and "Glacial deposits of southwestern Alberta in the vicinity of the Rocky Mountains."[1]

The observations made are in effect such as to lead the writer to believe that the bowlder clays and other deposits of the glacial period covering a large part, at least, of the Great Plains in Canada, are glacio-natant deposits, not directly due to an ice-sheet and not calling for an extension of glacier ice as such to this part of the continent. He has further ventured to suggest that the water covering the western plains at this time may have been at the level of that of the sea and in more or less direct communication with it. The present note relates, however, to the discovery in the bowlder clays of the Great Plains of marine organisms which appear to be contemporaneous with their deposition, and the general observations above alluded to need only be mentioned in introducing the subject.

Some time ago Mr. T. Mellard Reade, writing in comment on the paper last referred to above, and in the light of his own investigations and those of Mr. Joseph Wright on the bowlder clays of Great Britian,[2] suggested that a search should be made for

[1] Trans. Royal Soc. Can., Vol. VIII, Sec. 4 (1890). Bull. Geol. Soc. Am., Vol. VII, (1895).

[2] Cf. Present Aspects of Glacial Geology, T. M. READE, Geol. Mag. (IV,) Vol. III, p. 542. Bowlder Clay a Marine Deposit, J. WRIGHT, Trans. Geol. Soc. Glasgow, Dec. 1894 and May 1895.

micro-organisms in the bowlder clays of the plains. In conjunction with Mr. B. W. Thomas, I had some years ago examined several of these clays microscopically, but, as pointed out by Mr. Reade, the material examined in this case, was, in consequence of the mode of preparation adopted, that resulting from the elimination of all lighter particles by successive decantations, and not likely to include any foraminiferal forms still unfilled with mineral matter, which as a rule contain sufficient air to float to the surface of the water employed. In respect to the existence of forms contemporaneous with the deposit of the bowlder clays, the results arrived at by me were scarcely more than negative, but foraminifera evidently derived from the Cretaceous strata of the region were found in some of the clays from the Northwest.[1] Mr. Wright having very kindly offered to examine some of the western bowlder clays by the methods found applicable by him to those of Great Britian, several specimens were collected for the purpose and submitted to him. The results arrived at form the subject of this note, which is, however, essentially of a preliminary character, and is intended to be followed by further investigation as soon as it may be possible to obtain additional material.

The specimens sent to Mr. Wright were from the following places:

Nos. 1 and 2. Saskatchewan River, twelve miles below Victoria, collected by Mr. R. G. McConnell. These represent a bed of bowlder clay about fifty feet thick, the first being from its upper, the second from its lower part. Present height above the sea level about 1850 feet.

No. 3. Bowlder clay from near Victoria, Saskatchewan River, one and one-half miles up Egg Creek, also collected by Mr. McConnell. Height about 1900 feet.

No. 4. Bowlder clay from Selkirk, Red River, Manitoba. Collected by Mr. J. B. Tyrrell. Height above sea, 720 feet.

To these specimens from the West was added one collected by Dr. H. M. Ami, at Ottawa (No. 5).

It is not certainly known whether the bowlder clay represented by the first three specimens is the "lower" or "upper"

[1] Bull. Chicago Acad. Sci., Vol. I, No. 6 (1885).

bowlder clay elsewhere recognized in the western part of the plains,[1] but it is probably the latter. Microzoa were found only in the three samples from the Saskatchewan Valley. In giving the results of his examinations Mr. Wright writes as follows:

"In the clays from Victoria (1, 2 and 3) I find foraminifera (and Radiolaria) and I am of opinion that they are contemporaneous with the clay and not derived from Cretaceous strata—I judge by the general resemblance of the foraminifera to those we find in British bowlder clay. The foraminifers in the Cretaceous rocks of Canada may possibly be different to those which occur in the rocks of this age with us—I have never seen Cretaceous microzoa from Canada and so can give no opinion on this subject.

"Our chalk foraminifera are invariably of a dull white chalky appearance, the tests alone being calcareous, the interior being usually siliceous. On the other hand, our bowlder clay foraminifera differ in no respect from recent specimens, except in being usually smaller in size, the species being such as are now met with in shallow water around our coasts.

"All the species which I have been able to identify in the clays you sent me, are referable to recent species, and with the exception of *Cristellaria Italica* and *Rotalia orbicularis*, have been found in British bowlder clay. *Nonionina depressula* is the most abundant form in our bowlder clay, and it is instructive to find the species, so common with us, also occurring in your clay.

"*Bolivina lævigata*, *Cristellaria Italica*, as also some of the other specimens, have the clear hyaline luster of recent specimens. If Cretaceous, we would expect to find *Globigerina Cretacea* and *Textularia globulosa* plentiful."

The above references to Cretaceous foraminifera, are explained by the fact that Mr. Wright's attention had been called, when the specimens were sent, to the probable existence of such forms in the bowlder clays.

In replying to the letter from which I have just quoted, half a dozen specimens of Cretaceous foraminiferal material from the

[1] Cf. Bull. G. S. A., Vol. VII, p. 60.

Canadian Northwest, collected by Mr. J. B. Tyrrell, were sent to Mr. Wright, and allusion was also made to the report by Messrs. A. Woodward and B. W. Thomas on the "Microscopic Fauna of the Cretaceous in Minnesota, Nebraska and Illinois."[1] In this report, all the foraminifera found in bowlder clays, as well as those actually obtained from Cretaceous rocks, are classed together as Cretaceous.

After carefully examining the Cretaceous material sent, and preparing lists of the forms represented, Mr. Wright notes the occurrence in it of a great preponderance of the two species already mentioned by him as likely to be characteristic. He further points out that these Cretaceous foraminifera are filled with calcite, differing in that respect from most of those of the same age in Great Britain, but none the less stony and unlikely to float during the treatment of the clays. In Yorkshire he has met with clays containing about equal proportions of Cretaceous (derived) and Pleistocene (contemporaneous) foraminifera, but found no great difficulty in separating the two lots by the criteria already alluded to. Referring to Messrs. Woodward and Thomas' report, he expresses the belief that it really comprises a mixed fauna of the same kind, stating that of twenty-nine species recognized by these gentlemen, ten had not before been recorded from rocks of Cretaceous Age, according to Brady's monograph in the Challenger report.

One of the localities mentioned by Messrs. Woodward and Thomas for foraminiferal bowlder clay, that of South Chicago, lies so far from known Cretaceous outcrops and away from the line of any recognized drift from such outcrops, that I ventured to address a question on the subject of the probable origin of the microzoa to Professor T. C. Chamberlin. The foraminifera found in this bowlder clay, appear to be in part, at least, undoubtedly Cretaceous in age. In reply, Professor Chamberlin quotes observations made in northern Wisconsin which tend to show the existence of Cretaceous outliers there, as well as perhaps beneath the northern part of Lake Michigan, or even further east. He

[1] Geology of Minnesota, Vol. III, Part I (1895).

writes: "Taking the evidence all in all, I do not think there is any serious difficulty in accounting for Cretaceous forms in the drift of this region" (Chicago). After referring to the interest attaching to Mr. Wright's observations, he adds the following interesting suggestion concerning them: "It has occurred to me to raise the question whether a certain number of marine microscopic forms are not to be expected in any slow-accumulating deposit like a clay, in the interior of the continent, having been borne there by the wind with other dust picked up from marine flats on the windward side of the continent."

The purpose of this communication is accomplished in stating as above, briefly, the new facts which appear to bear upon the question asked in its title. It seems to be at least very probable that, in addition to derived Cretaceous foraminifera often found in the drift deposits of the Great Plains, we have contemporaneous forms of the sea of the glacial period, still unfilled with mineral matter, unaltered, hyaline in aspect, and representing the same species elsewhere commonly found in deposits of this period. Should further investigation confirm the contemporaneous and autochthonous character of this fauna, it will greatly assist in enabling the formation of definite hypotheses respecting events of the glacial period in the western part of the continent.

Mr. Wright's notes on the specimens of bowlder clay from the Saskatchewan, are as follows :—

No. 1. Bowlder clay, twelve miles below Victoria. Weight 4 lbs. 4.5 oz Troy. After washing — Fine 1 lb. 3.7 oz. Course 0.7 oz. Stones mostly rounded, some angular.

Gaudryina Sp., very rare.
Bulimina pupoides D'Orb., frequent.
Pulvinulina Karsteni (Rss.), very rare.
Nonionina depressula (W. & J.), very rare.
Rotalia orbicularis, D'Orb., very rare.
Radiolria, frequent.
Sponge spicules, rare.

No. 2. Bowlder clay, twelve miles below Victoria. Weight 2 lbs. 6.2 oz. Troy. After washing — Fine 8.9 oz. Coarse 0.5 oz. Stones mostly rounded, some angular.

Bulimina pupoides D'Orb., rare.
Bolivina lævigata (Will.), very rare.
Cristellaria Italica, Defr. (young), very rare.
Truncatulina Sp., very rare.
Rotalia orbicularis, D'Orb., very rare.
Radiolaria frequent.
Sponge spicules, rare.

No. 3. Bowlder clay near Victoria. Weight 3 lbs. 1.6 oz. Troy. After washing — Fine 1 lb. 0.1 oz. Coarse 0.6 oz. Stones mostly rounded, some angular.

Gaudryina Sp., frequent.
Bulimina pupoides, D'Orb., rare.
Rotalia orbicularis, D'Orb., frequent.
Nonionina depressula (W. & J.), very rare.
" *scapha* (F. & M.)? very rare.
Radiolaria, frequent.
Sponge spicules, rare.
Ostracod, very rare.

It may be of interest to add for comparison, the species actually recognized by Mr. Wright in the several small samples of Cretaceous material supplied to him. These are, nearly in order of relative abundance, as follows :—

Textularia globulosa Ehr., very common.
Globigerina Cretacea, D'Orb., very common.
" *digitata*, Brady, rare.
Anomolina ammonoides, (Rss.), rare.
Nodosaria Zippei, Rss., very rare.

GEORGE M. DAWSON.

GEOLOGICAL SURVEY OF CANADA,
March 10, 1897.

THE BAUXITE[1] DEPOSITS OF ARKANSAS.

CONTENTS.

Previous publications.
Definition and composition.
Structure and appearance.
Geologic age.
Origin.
Forms of the deposits.
Methods of mining.
Uses.
Bauxite as a refractory material.
Markets.
Bibliography.

THE geological survey of Arkansas was begun in June 1887. In that month I discovered some of the bauxite beds of Pulaski county, but the nature of these deposits was not announced until January 1891, when I gave a short account of their distribution and character.[2]

The many inquiries concerning the Arkansas bauxites, both from geologists and manufacturers, furnish sufficient reason for the present more extended account of them. This is made still more necessary by the fact that my report on the clays, kaolins, and bauxites of Arkansas has not yet been published, and it seems improbable that it ever will be published by that state.

In view of the fact that Owen was State Geologist of Arkansas from 1857 to 1860, and that other surveys were carried on

[1] This is also sometimes written *beauxite*. The word is derived from Les Baux or Les Beaux, the name of a town in the south of France. Pronounced *bozite*, not *bawksite*.

[2] A letter on this subject was addressed to Governor James P. Eagle and was printed in the *Arkansas Gazette* and the *Arkansas Democrat* of January 8, 1891, and reproduced in the *Arkansas Press* in several numbers from January 18, 1891, until 1893, and also in the third and fourth biennial reports of the Commissioner of Mines, etc., of the state of Arkansas. A brief notice of the deposits was also published in the *American Geologist* for March 1891, pp. 181–183.

from 1871 till 1874,[1] it is somewhat remarkable that the bauxite deposits were not sooner discovered. The rocks were seen and mentioned by two geologists, but their true character and importance were not suspected. As long ago as 1842 Dr. W. Byrd Powell published a brief paper on the geology of Fourche Cove, near Little Rock, in which he says:[2] "There is an extensive amygdaloid formation within the cove, and also upon the eastern side of it (page 11) . . . . The amygdaloid proper is of a light brick color. In some localities it is darker, and in others lighter . . . . At one locality the amygaloids are small, resembling a mass of peas, ... but each amygaloid, or pea-like body, is hollow, having a shell not thicker than that of an egg. At another the amygdaloids are filled, but they, as well as the cement or gangue, are earthy and more or less friable." There can be no doubt that some of these so-called amygdaloids are the bauxites.

It is evident, however, that some of the tertiary conglomerate beds were regarded by Dr. Powell as variations of these "amygdaloids," for he says that some of them consist of jasper (p. 12).

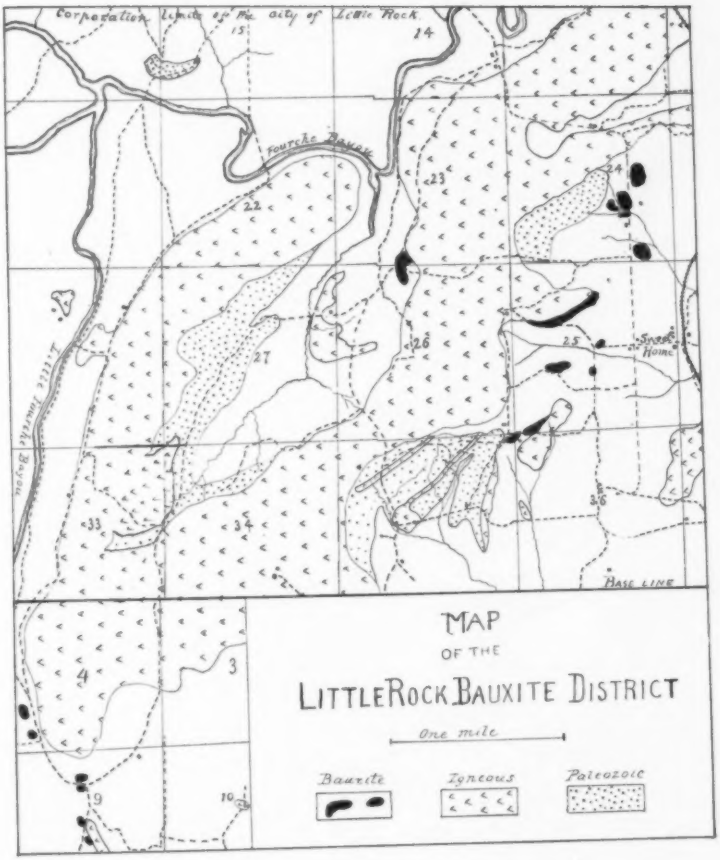
Owen also mentions this "ferruginous amygdaloid of rather a peculiar character," and says that "the amygdules are very globular, so that the rock has much the appearance of peastone, the cavities being mostly empty."[3] The description of the rock and the locality given make it clear that the bauxite rock is here referred to, and yet there is no word to show that either Powell or Owen knew or suspected the true nature of the material.

That these observers did not recognize this mineral is probably due to the fact that bauxite was, at that time, but little

[1] See the Geological Surveys of Arkansas, by J. C. BRANNER. JOUR. OF GEOL. II, November–December 1894, 826–836.

[2] A geological report upon the Fourche Cove and its immediate vicinity, by W. BYRD POWELL, M.D., Little Rock, 1842, 11–13. This is a very rare pamphlet; I know of but one copy of it, and that is in the library of the U. S. Geological Survey.

[3] Second report of a geological reconnoissance of Arkansas. By DAVID DALE OWEN, Philadelphia, 1860, 70.


Corporation limits of the city of Little Rock
Fourche Bayou
Little Rock Bayou
Spring Home
Base Line
MAP
OF THE
LITTLE ROCK BAUXITE DISTRICT
One mile
Bauxite
Igneous
Paleozoic

known even in Europe, and it was altogether unknown in America.

At the time when it was found that this rock was bauxite (1887) it was being used extensively for making the roadbed of the Little Rock and Sweet Home turnpike, especially along the part of the road near one of the bauxite beds. It had also been recommended by a former state geologist, Mr. W. F Roberts, Sr., as a "pisolitic iron ore," and attempts had been made to mine some of the highly colored Saline county beds for iron.

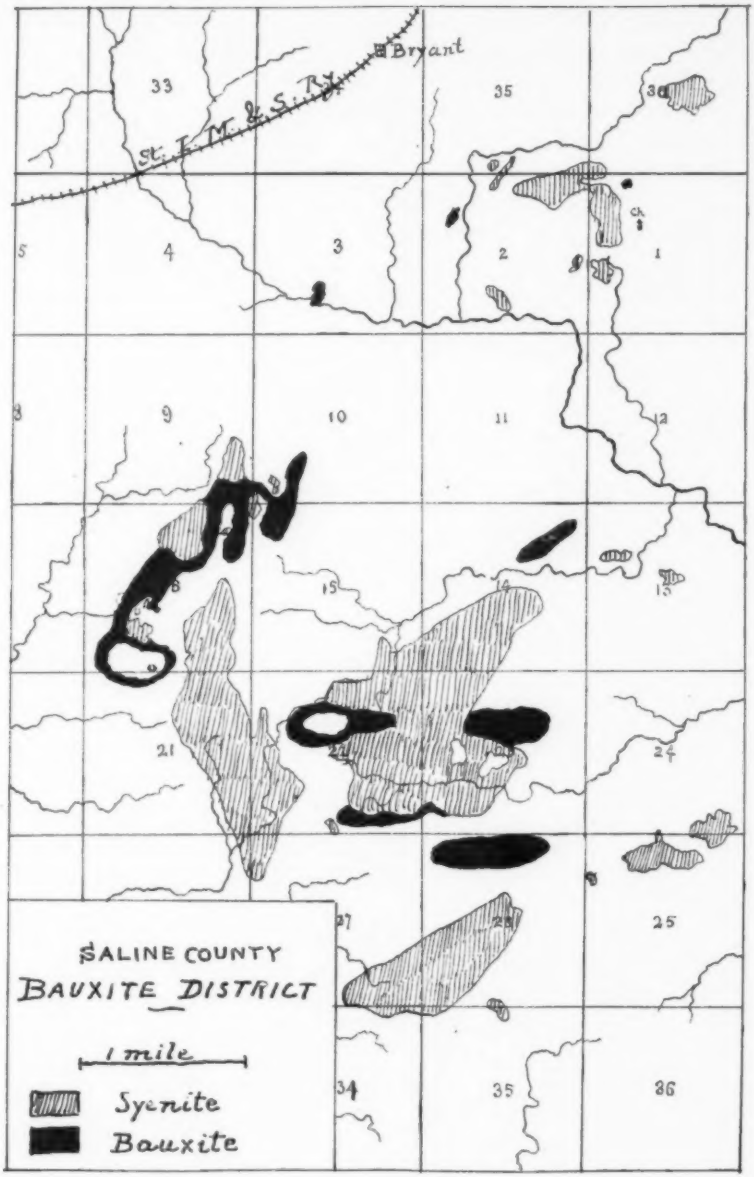
Definition and composition.—It is practically impossible to draw a sharp line of division between bauxite as defined mineralogically and what appears in a hand specimen to be the same thing, but which on analysis is found to contain one or another impurity in such proportions as to throw it out of the bauxite list. Mineralogically bauxite is a hydrate of alumina,[1] but it is never found without certain impurities, the common ones being iron, silica, potash, soda, and titanium. All these impurities are found in the Arkansas bauxites, and in some cases the iron is so abundant that the beds have been prospected with a view to using the material as an ore of iron. The following analyses of some of the more ferruginous varieties show its iron contents:

ANALYSES OF FERRUGINOUS PISOLITIC BAUXITE.

Number	Percentage of iron	Phosphorus	Silica
1	66.85	.043	not det.
2	54.2	.048	not det.
3	59.2	.031	not det.
4	54.9	.10	1.99

No. 4 was collected by the writer in 2 S. 14 W. section 1, northwest quarter; the other numbers are from the Saline

[1] St. Claire Deville regards it as a variety of Diaspore ($Al_2O_3H_2O$); Dufrenoy thinks it is close to Gibbsite ($Al_2O_3 3H_2O$), while Liebrich shows it to be closely related to or identical with Hydrargillite.


Bryant
St. L. M. & S. Ry.
33
35
36
5
4
3
2
1
8
9
10
11
12
15
14
15
21
24
27
28
25
34
35
36
SALINE COUNTY
BAUXITE DISTRICT
1 mile
Syenite
Bauxite

county deposits, but they were collected by prospectors for iron ore, and their exact locations are not known.

In other cases the bauxite contains so much silica and so little water that it is not to be distinguished by analysis from ordinary kaolin. And these varieties grade so insensibly into each other that no line of demarkation can be drawn between them. The following analyses show the similarity in composition between a kaolin and a variety of bauxite, which, properly speaking, is simply a pisolitic kaolin.

ANALYSES OF PISOLITIC AND ORDINARY KAOLINS.

	Pisolitic kaolin 1 S. 13 W., sec. 10 N. E. of N. E.	Pisolitic kaolin Same sec., S. E. of N. W.	Washed kaolin from Brandywine Summit, Pa.
Silica, SiO_2	48.05	45.20	47.24
Alumina, Al_2O_3	38.92	37.60	37.27
Ferric oxide, Fe_2O_3	1.19	3.00	1.94
Lime, CaO	0.58	.89	0.52
Magnesia, MgO	0.45	.00	trace
Potash, K_2O	0.18	.06	0.22
Soda, Na_2O	0.28	.69	0.13
Water	10.86	13.54	13.62
Total	100.51	100.98	100.94

Water at 110°–115° C.....0.46 %.....1.48 %

In the following table are brought together all the analyses of the Arkansas bauxite, and a few analyses of representative bauxites from other parts of the world.[1] These analyses are of individual examples, however, and must not be accepted as if made of car-load lots.

[1] In the article published in the *American Geologist* for March 1891 I gave an average of fourteen partial analyses of bauxite from France, Austria, and Ireland. I wish here to express my disapproval of such a method of making comparisons. Owing to the extreme variability of bauxites, even from the same beds, such an average can scarcely fail to be misleading. If material is wanted with a low percentage of silica the high percentage in some of the samples will so increase the silica in the average that one may be led to infer that none of it is low enough to be available — a conclusion entirely unwarranted.

ANALYSES OF ARKANSAS AND FOREIGN BAUXITES.

	Silica SiO_2	Alumina Al_2O_3	Iron Fe_2O_3	Titanic oxide TiO_2	Water H_2O	Color
1	10.13	55.59	6.08	....	28.99	Light brown
2	11.48	57.62	1.83	....	28.63	Gray
3	3.34	58.60	9.11	....	28.63	Light red
4	4.89	46.44	22.15	....	26.68	Brick red
5	5.11	55.89	19.45	....	17.39	Black
6	33.94	44.81	1.37	2.00	17.88	Gray, surface
7	2.00	62.05	1.66	3.50	30.31	Pink
8	10.38	55.64	1.95	3.50	27.62	Surface
9	16.76	51.90	3.16	3.50	24.86	
10	45.20	37.60	3.00	....	13.54	Lime 0.89 Potash .06 Soda .69 White, pisolitic
11	21.70	58.10	3.00	3.20	14.00	White
12	2.80	57.60	25.30	3.10	10.80	Red
13	6.29	64.24	2.40	some	25.74	

1. 1 north, 12 west, section 24, north side of the southeast quarter. On Little Rock Sweet-Home turnpike, cut near road.

2. 1 north, 12 west, section 25, southwest corner, and section 36, northwest corner. Tarplay's.

3. 2 south, 14 west, sections 9 and 10; extending also from 10 into northwest of 15.

4. 2 south, 14 west, section 3, southeast of the southwest.

5. 2 south, 14 west, section 3, southeast of the southwest.

6. 2 south, 14 west, section 16, northeast corner of the southwest quarter near Sol. Nethercut's.

7. 1 south, 12 west, section 9, northwest quarter of the northeast quarter, at the end of the Arch Street Pike, and just north of the fork of the road at the point mentioned.

8. 1 south, 12 west, section 4, middle of the south side of the northwest of the southwest quarter on the west side of the Arch Street Pike leading south from Little Rock. Exposure in the field, a stone's throw from the road.

9. 1 south, 12 west, section 9, northeast quarter of the northwest quarter, west of the pike and west of small stream, about 100 feet south of bridge.

10. 1 south, 13 west, section 10, southeast quarter of the northwest quarter.

11. Baux, near Arle, France (Sainte-Claire Deville).

12. Revest, near Toulon, France (Sainte-Claire Deville).

13. Near Feistritz, Styria.

The analysis must determine the value of bauxite, but it should not be forgotten that varieties not available for one purpose may sometimes be used for some other purpose. As a rule, however, silica, iron, and titanium are the objectionable ingredients. When the percentage of silica reaches that in kaolin or clay the bauxite has no advantage over kaolin or clay for the purposes for which it is used.

Mr. McCalley, in his valuable paper upon Alabama bauxite, calls attention to the fact that the surface material contains more silica than samples taken at a depth.[1] This had escaped attention in my brief examination of the Arkansas bauxite, but since reading Mr. McCalley's paper I recall the fact that this view is borne out by the analyses of the Arkansas materials so far as they have been made. If this is a fact that can be depended upon as constant, it is one of great importance in mining bauxite.

In the ferruginous, earthy, and kaolin-like varieties the pisolitic structure is always more or less pronounced in the Arkansas bauxite.

Structure and appearance.—Bauxite is very light; its specific gravity is about 2.4. In gross structure, color, texture, and general appearance Arkansas bauxite varies greatly. The colors are red, pink, brown, black, gray of various shades, white and yellow, and these colors are also more or less mixed in the same deposit, and even in the same hand specimen.

The several classifications or subdivisions proposed by Coquand, Laur and others will, in all probability, hold with the Arkansas deposits, but inasmuch as these divisions all grade insensibly into each other it seems unnecessary to give those classifications or to lay any stress upon them. Chemical analyses and the practical availability of the different varieties can alone be

[1] Proc. Ala. Ind. and Sci. Soc., Vol. II, 1892, p. 29.

depended upon. I may add, however, as a suggestion of possible utility that the red varieties are not all high in iron as one might suppose; some of the reddest examples found in Saline county contain very little iron.

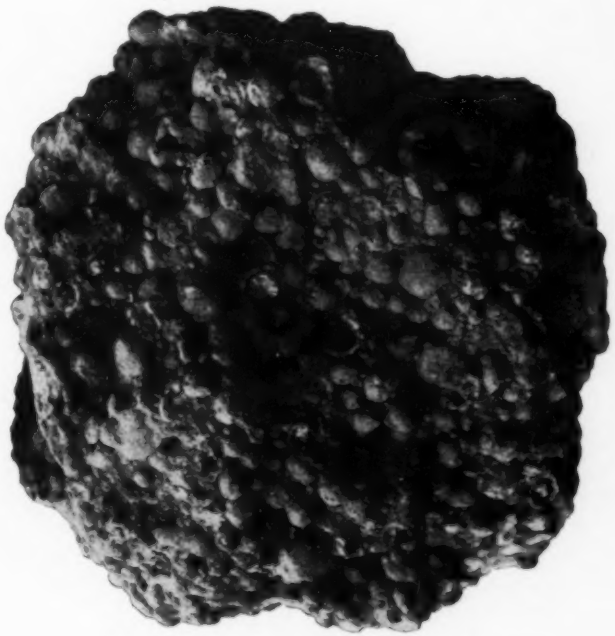


FIG. 1. Pistolitic Bauxite from near Little Rock.

Some of the pisolites are solid and some of them are hollow; sometimes they are scattered through a more compact and homogeneous groundmass, and at other times they make up the body of the rock and resemble a great mass of peas cemented together.

The accompanying illustration (Fig. 1) shows a specimen of the more pisolitic variety taken from the deposits in township 1 south, 12 west, section 4, southwest quarter.

The pellets are in some place much larger, the biggest being the size of one's two fists or even larger.

Bauxite is sometimes compact. Mention should be made of the fact that while one often sees small pieces of the compact variety, there are, so far as I know at present, no beds or considerable deposits of the compact kind in Arkansas.

I have seen in the Royal College of Sciences in Dublin specimens of the compact bauxite of Ireland. That material looks very like a compact and homogeneous clay, and has no evidences of pisolitic structure. Bauxite of this variety I have not found in Arkansas.

The heavy beds in Saline county are in some respects different from those at the other Arkansas localities. In small fragments this material is not distinguishable from that found near Little Rock, but the beds are, in places, made up of what seem to be cobbles or rolled and waterworn lumps of the same material. Some of these lumps are as large as a man's head.

Under the microscope one specimen shows the pisolites to be concentric in structure, while here and there through them are thin bands or veins of quartz. This suggests that the silica found by analysis is sometimes free.[1]

Geologic age.—Bauxite has been found in Arkansas only in Tertiary areas and in the vicinity of eruptive syenites with which I believe them to be genetically related. This statement concerning areal distribution must be accepted simply as a statement of fact, but one that may be of considerable importance in Arkansas, and possibly of none whatever in other bauxite regions. The evidence of the Tertiary age of the Arkansas bauxite is not abundant, but it all points in one direction.

At the village of Ridgewood, about five miles south of Little Rock, a well dug on lot 11 exposed the following section:

Section of well on lot 11, village of Ridgewood.—

3 feet surface soil.

7 feet pisolitic bauxite.

[1] For a good microscopic view see paper of C. W. HAYES in the 16th Ann. Rep. U. S. G. S., Part III, Plate XXIII.

2 inches iron (limonite.)
6 inches pink and white clays.

The pink and white clays at the bottom of this well belong with the horizontally stratified Tertiary beds of the neighborhood. There are no fossils, however, in these clays, and they are considered as Tertiary solely upon lithologic and stratigraphic grounds.

At Tarplay's place in the northwest corner of section 36, 1 north, 12 west, the bauxite has a thin bed of Tertiary or post-Tertiary sandstone overlying it. At Mabelvale in 1 south, 13 west, section 10, northwest quarter, the same kind of ferruginous sandstone overlies bauxite. It should be added also that the bauxite at several places overlies the eruptive syenites or so-called "granites," while at several others it is very probable that there are syenites beneath them. These syenites are apparently of late Cretaceous or post-Cretaceous Age.

It is not to be inferred, however, that bauxite is confined to Tertiary rocks, except perhaps in Arkansas. I see no reason why the conditions that produce this mineral might not exist in one age as well as in another, though these conditions are likely to occur in one age in one place and in another age at another place.

The statement of Laur that "the phenomena which gave rise to the bauxites in Europe occurred with great intensity toward the end of the Cretaceous epoch, and has never been repeated"[1] is probably unwarranted.

In southern France bauxite is said to form the parting between the Cretaceous and the Jurassic. Coquand says it is in the *Lychnus* beds of the Upper Cretaceous.[2] Collot shows that it lies between the Urgonian below and the Cenomanian above, that is, about the junction between Lower and Upper Cretaceous.[3] Rouville says the pisolitic iron of Herault is in the "Oxfordian" or Upper Jurassic, if by "Oxfordian" he means

[1] Trans. Amer. Inst. Min. Eng. 1896.

[2] Bull. Soc. Géol. 1870–1, XXXVIII, 111.

[3] Compt. Rend. 1887, CIV, 129–130.

the Oxford clays of the English geologists.[1] Fabre found it in crevices in Jurassic rocks,[2] but deposited in early Tertiary times, while that referred to by Dr. Raymond in a corundum mine in North Carolina is believed to be in eruptive rock,[3] the age of which is not stated. The Irish bauxites are associated with eruptive rocks of Tertiary Age.[4]

The Alabama bauxite deposits are said[5] by McCalley to be of Lower Silurian Age, but Hayes thinks[6] the Alabama and Georgia deposits were formed "toward the close of the Eocene."

These cases are cited simply to show that bauxite is not confined to rocks of any particular age, except perhaps in a given region. I have seen it stated that bauxite has been found recently near the Maumelle Pinnacles, about fifteen miles up the river from Little Rock. This would bring the deposits into rocks of Carboniferous Age This report lacks confirmation; I know of neither bauxite nor syenite in that region. It is important to notice, however, that if the writer's theory of the origin of these deposits is correct, search for them in Arkansas should be confined to the neighborhood of the eruptive syenites,[7] though not all these syenites have bauxite deposits in their vicinity. The eruptive rocks at Magnet Cove are mostly syenites, but no considerable bauxite deposits have been found associated with them. Some small fragments were found by me in the Cove on the north slope of the hill just south of the Baptist church.

Origin of the Arkansas bauxite deposits.— In searching for new deposits and in determining the limits of those already known, we must be guided to a certain extent by a knowledge of the method

[1] Bull. Soc. Géol. de France XXV, 1867-8, 935.

[2] Bull. Soc. Géol. de France, 1869-70, XXVII, 518.

[3] Trans. Amer. Inst. Min. Eng. VII, 86.

[4] Memoirs of the Geol. Survey [of Ireland] to accompany sheets 7, 8, 14, 20. By R. G. SYMES.

[5] Alabama bauxite. By HENRY MCCALLEY. Proc. Ala. Ind. and Sci. Soc., 1892, II, 21.

[6] Bauxite. By CHARLES W. HAYES, 16th Ann. Rep. U. S. Geol. Sur., Part III, 592. Washington, 1896.

[7] For the distribution of eruptive rocks in Arkansas see Vol. II of the annual report of the Geological Survey of Arkansas for 1890.

by which the deposits have been made, for it is only in this way that we can anticipate the peculiarities of its distribution. There is therefore given below, as briefly as possible, the several theories that have been advanced to explain the method by which bauxite deposits have been made.

The Arkansas beds appear to have been laid down in water near the shore, but the material does not seem to have been car-

FIG. 4. Ideal Section through Fourche Cove.

ried far from the spot at which it originated, or to have been widely distributed by the water. They are all at or near the contact between the palæozoic sediments and the eruptive syenites. Several of them, however, have no palæozoic rocks exposed near at hand, and one of them has no syenite exposures. These conditions are shown in part by the following ideal section illustrating the relations of the rocks about the Fourche Cove.

The concretionary structure of the bauxite suggests that it has been formed in some such manner as the oölites or sprudelsteins of the well-known hot springs at Carlsbad. At this last named place the oölites are made of carbonate of lime. The water is charged with lime, and as it issues the lime collects about centers. These masses are kept in motion in the rising waters until by accretion they become so heavy that they sink to the bottom.

Oölites are also made in various other ways, such as the rolling of grains upon a shore and in waters heavily charged with lime, by lime secretions of certain algæ[1] and other organisms,[2] and possibly by insect eggs as suggested by M. Virlet d'Aoust.[3]

[1] On the formation of oölite. By DR. A. ROTHPLETZ. Amer. Geol. X, 279–282.

[2] The formation of oölite. By E. B. WETHERED. Quar. Jour. Geol. Soc., LI, 1895, 196–209.

[3] The Geologist (I), 1858, 72–73.

Attention is directed to the peculiar nature of some of the great beds of Saline county; there the strata are composed of rolled or waterworn lumps as large as one's head which, when broken open, show the same pisolitic structure as that found at other places. It looks as though the material had been deposited in water near the shore, and that it had been partly uncovered at low tide or broken up by storm waves, and that its earthy material had been broken and rolled by the waves, and finally left at or near where it had originally lain. None of the beds examined show the lamination or thin bedding planes so characteristic of sedimentary rocks.

These facts seem to point to an origin for bauxite very similar to that of calcareous pisolites, and its association with the syenites suggests that the latter have something to do with the matter. I am of the opinion that the explanation offered by Coquand, Augé, de Rouville,[1] Virlet d'Aoust,[2] Daubrée,[3] and Hayes is the correct one so far as hot waters are concerned, but I am unable to see why they should have been geyser waters. Augé has cited[4] from Hayden's report of 1878, Part II, p. 416, what he considers a case of bauxite actually forming in a geyser. This, however, is a mistake: I have examined in the United States National Museum the material referred to; it has no resemblance to bauxite, and Professor George H. Merrill tells me that it is a geyser mud or kaolin mechanically churned up by the water and from which the silica has been removed. Strangely enough this error has been extensively copied and is found in many of the papers on bauxite, even as late as that by M. Lauer published in 1895.

Dr. Genth holds that the bauxite may be derived by hydration from corundum, but frankly admits that he cannot explain the transformation.[5]

[1] Bull. Soc. Géol. de France, 1867-8, XXV, 935.

[2] Op. cit., XV, 199; XXII, 418-420.

[3] Op. cit., XXVI, 915.

[4] Bull. Soc. Géol. de France, 1888, XVI, 345-350.

[5] Proc. Am. Phil. Soc. Vol. XII, 373 and 405.

Coquand says:[1] "The aqueous origin of the bauxites is as well marked by their structure as by their stratification and alternation with sandstones, limestones, and clays. It is evident that the sedimentation (at the time the deposits were made) began at the bottom of a lake by the deposition of aluminous and calcareous matter brought in from mineral sources and to which a certain movement of the waters gave a pisolitic form." It is not altogether clear what M. Coquand means by the "mineral sources" to which he refers several times and to which he attributes the material of the bauxites. His paper ends with the conclusion that the several bauxite localities of France "are of the same age and fall under the head of irregular deposits of geyser origin," from which it must be inferred that he thinks the hot waters of geysers are the "mineral sources" from which the bauxite has been derived.

M. Stanislas Meunier holds[2] that salt water penetrating to great depths can, on account of its high temperature and the pressure upon it, dissolve the ferruginous shales and form chlorides of alumina and perchlorides of iron. When these chlorides come to the surface and spread over limestones, as they usually do, a change of bases takes place, alumina and peroxide of iron are precipitated, chloride of lime is carried away and the carbonic acid of the limestone is set free, while the iron and alumina is deposited as bauxite.

Augé, as stated in the article already referred to, was led to reject Meunier's theory by finding bauxite resting on rocks other than limestones. To this Meunier replies that the chemical changes demanded by his theory might be produced by the waters carrying the material passing over limestones and depositing the bauxite further on in their course.

Daubrée says[3] that while generally associated with sedimentary beds, the bauxite beds show their relations to deep-seated emanations by the presence of anhydrous peroxyde of iron or

[1] Bull. Soc. Géol., 2me ser., 1870–1, XVIII, 98 ff.

[2] Bull. Soc. Géol., 3me ser., XVI, 1888, 345–346.

[3] Bull. Soc. Géol. de France, XXVI, 1868–9, 915.

oligiste, which generally colors them, and by its ramifications generally penetrating underlying beds and by the juxtaposition to granite.

R. G. Symes thinks that the bauxite at Estertown, County Antrim, Ireland,[1] "seems to be a mud lava."

The most exhaustive study yet made of bauxite is that of Dr. A. Liebrich, the title of whose treatise is given in the bibliography at the end of this paper. He quotes Streng as holding that the Vogelsberg bauxite is derived from basalt by decomposition, and, in general terms, Liebrich endorses this view. Further on, however, he states that it is "not the decomposition product of an underlying basalt, but of a completely disintegrated anamesite lying above a compact basalt." Again he says: "There is nowhere bauxite containing a kernel of stone which is not a decomposition product." Again "the transition between bauxite and basaltic hematite may be traced step by step in thin sections." Also; "it is to be regarded as a concretionary formation which has originated in the clay formed by decomposition of rock, and that it is therefore not a simple process but several different processes following each other." He thinks, however, that other kinds of basalt than anamesite can yield bauxite. He also concludes from his microscopic and chemical studies of bauxite that it is the same as hydrargillite. The chemical process and the method of forming the pisolites, he says, is unknown.

Of the theories above mentioned the only one that appears to be applicable to the Arkansas deposits is that of hot waters. This however is not necessarily in conflict with the theory of Liebrich that they are decomposition products, though they are not, in the present case, associated with basalts, and are certainly not formed by the decomposition of any rock *in place*. It is my opinion that before the eruptive syenites had cooled they were sunk beneath the Tertiary sea, and that either by the contact of the sea water or by the issuing of springs whose waters

[1] Memoirs of the Geological Survey of Ireland, Mem. accompanying Sheet 20, p. 12.

had been in contact with the hot syenites the aluminous materials were seggregated as pisolite and sank near where they were formed. Thus if the process is one of decomposition it is decomposition in the presence of and due to high temperature.

The irregular forms of the deposits, their variable thicknesses and characters, and, in fact everything known about them, is in keeping with this theory of their origin. Stress has been laid by Meunier upon the fact that so many bauxites rest upon[1] or are associated with limestones; and this fact was used by him to explain the precipitation of the material from chlorides of aluminium in hot sea water. But, as Augé has pointed out, limestones are not always present,[2] and there are certainly none associated with the Arkansas deposits.

Forms of the deposits.—From what has been said it is evident that the bauxite deposits must be very irregular in form. Although associated with marine sediments of wide and regular distribution, the bauxite deposits are local, irregular and of uncertain extent, for the influences that produced them were local, and the rocks (syenites) with which they are associated are in all probability concealed in many places. The figure given under the head of "origin" on page 275 will give as definite an idea as can be had of the forms of the deposits without prospecting. If, at any time, it should become necessary to prospect for other deposits, the prospecting should be confined to the region in which bauxite is now known and to the soft Tertiary beds. It does not now seem advisable to look for this mineral above an elevation of 350 feet or below 250 feet above mean tide.

Method of mining.—Stripping and quarrying in open cuts is the method to be used in nearly all the deposits known. Of course when the cover becomes too thick it cannot be removed economically, and such deposits will either have to be abandoned or the mining will have to be done by drifts. Persons experienced in the driving of tunnels and mine timbering should

[1] Comptes Rendus, 1883, XCVI, 1737–1739.

[2] Bull. Soc. Géol. de France, 1888, XVI, 346.

have charge of the work in this stage. The roof is likely to be soft and to require lagging. Furthermore, unless discretion is used in opening quarries and driving tunnels, the operators are likely to have difficulty with the draining of the mines.

THE DISTRIBUTION OF BAUXITE IN ARKANSAS.

In thickness the bauxite beds vary greatly, the greatest found being forty feet, and even in this case the full thickness of the bed is not exhibited. In vertical distribution it has a range of about sixty feet, lying, so far as observed, between 260 and 320 feet above mean tide level. This observation, however, refers only to the Pulaski county deposits, no observations having been made on the vertical range of the Saline county beds, which, however seem to be at, or near, the same elevation. It is not supposed that the exposures now known are the only ones in the state, for it has not been possible to make detailed search throughout the area in which the deposits may reasonably be expected. The number of exposures will probably not only be considerably increased, but it should be added, that inasmuch as sedimentary beds overlie or have overlain some of the known deposits, it is quite possible that there are others yet uncovered by natural processes of erosion.

These bed should be sought only in the areas of soft sands, clays, and gravels and in the neighborhood of the eruptive rocks of Saline and Pulaski counties.

THE USES OF BAUXITE.

Many attempts have been made to use bauxite as an ore of iron, but with poor success or with no success at all. The kaolinic varieties may be found available as kaolins, though I know of no attempts to use them for such purposes. Bauxite has been successfully used for the manufacture of the following materials:

1. Alum.
2. Sulphate of alumina.
3. Aluminum (the metal).

4. Refractory wares, such as furnace linings.

5. It is also available for increasing the refractoriness of fire clays used in the manufacture of fire bricks, furnace linings and the like.

I shall say nothing of the methods employed in the utilization of the raw material. Some of them are described in the works mentioned at the end of this paper, others are guarded as trade secrets, or are covered by patents.

There is one use, however, for which bauxite is available to which I wish to direct especial attention, and that is as a refractory material in the manufacture of iron and steel.

Bauxite as a refractory material.—Bauxite is one of the most refractory materials used in the arts. It is especially valuable for lining blast furnaces where it outlasts the best artificial fire bricks. It is used alone and also as an ingredient for increasing the percentage of alumina in other refactory materials.

In his "Feuerfesten Thone," Bischof speaks as follows of bauxite:[1] "This natural aluminium hydrate which has as yet been found only in a few places, ... when not impure on account of the admixture of foreign substances, especially of iron, which generally occurs in considerable quantities in compounds of alumina, is extremely refractory. . . . The addition of the varieties free from iron, or the white ones, to other refractory clays offers the only *important means known* of increasing their percentage of alumina, and at the same time their refractoriness. On account of a large percentage of chemically combined water this material shrinks considerably in burning, a fact to be noted in using it." In another place Bischof says:[2] "Bricks made from calcined bauxite are especially useful in the production of iron and steel in the Siemens revolving furnace."[3]

Bruno Kerl, an excellent authority on this subject, says:[4] "Bauxite bricks and crucibles of bauxite, recommended by

[1] Die Feuerfesten Thone, C. Bischof, pp. 193–4.

[2] Op. cit., p. 277.

[3] See also Dingler's Polytechnisches Journal, Vol. CXCVIII., p. 156; ibidem, Vol. CCX., p. 109.

[4] Thonwaarenindustrie, p. 526.

Gaudin as long ago as 1858, should, when low in iron, withstand heat which would fuse all other refractory materials.

"Bauxite is a compound having a composition intermediate between diaspore and limonite, and consists of hydrate of alumina combined with hydrated oxide of iron.

"On account of the large quantity of water present this mineral shrinks greatly on heating, is usually refractory, and, if it does not contain too much iron, when added to fire clays, increases their refractoriness.

"Siemens used bauxite bricks with 50 per cent. of alumina, 35 of iron oxide and 3 to 5 of silica, which lasts five or six times as long as Stourbridge first-brick. Schwarz recommends for crucibles for manufacture of cast steel a composition of one to two parts Goettweiher clay and two parts of burnt bauxite from Wochein. The bricks of the Compagnie Parisienne at the Vienna Exposition withstood the heat of molten platinum, yet their fracture was like that of stoneware."

Sir William Siemens tested bauxite as a furnace lining and says[1] of it: "A series of experiments to form solid lumps by using different binding materials have shown that 3 per cent. of argillaceous clay suffice to bind the bauxite previously calcined. To this mixture about 6 per cent. of plumbago powder is added, which renders the mass practically infusible, because it reduces the peroxide of iron contained in the bauxite to the metallic state. Instead of plastic clay as the binding agent, waterglass or silicate of soda may be used, which has the advantage of setting into a hard mass at such a comparatively low temperature as not to consume the plumbago in the act of burning the brick. A bauxite lining of this description resists both heat and fluid cinder in a very remarkable degree, as I have proved by lining a rotative furnace at my sample steel works at Birmingham, partly with bauxite, and partly with carefully selected plumbago bricks. After a fortnight's working the brick lining was reduced from six inches to less than half an inch; whereas the bauxite lining was still five inches thick and perfectly compact. It is

[1] The scientific works of Sir Wm. Siemens, I., London, 1889, 296.

also important to observe that bauxite when exposed to intense heat is converted into a solid mass of emery of such extreme hardness that it can hardly be touched by steel tools, and is capable of resisting mechanical as well as the calorific and chemical actions to which it is exposed.

"The bauxite used in the above mentioned lining was of the following composition:

Al_2O_3 - - -	53.62
Fe_2O_3 - - - -	42.26
SiO_2 - - - -	4.12"

Speaking of the value of bauxite as a refractory material Professor Thomas Egleston of the Columbia School of Mines says that it "lasts five or six times as long as the best Stourbridge bricks. Nothing has yet been found which resists the corrosive action of basic slags so well."[1]

In a letter to the author regarding bauxite as a refractory material Professor Egleston writes:

"If the material is pure there would be a very large demand for it. With the introduction of basic processes, the demand for basic lining has increased steadily, but on account of the uncertainty of the composition of bauxite, it is being very generally replaced by carbonate of magnesia, which is found in several localities in Europe and is imported both to England and this country."

The results of several analyses of Aakansas bauxites were sent Professor Egleston when he wrote:

"The subject is a very interesting one and may be of great value to the state if it should prove that any of these are aluminates. In some of them I fear there is too much silica, but in any case I think valuable fire bricks could be made of them. I have often tried to interest the fire-brick people in the new processes for the manufacture of these bricks which have been developed within the past ten or fifteen years in Europe, and in the hope of so doing have published several articles on the subject, but the manufacturers have been generally unwilling to

[1] Transactions Am. Inst. M. E., Vol. IV., 261–2.

invest any more capital in their business, which, they say is already very much cut up. If a new industry were started, it could be started on altogether a different basis and I think would easily compete with the old manufactories. This is all the more true since the development of the basic open hearth and Bessemer process in the South calls for a higher grade of fire-brick. I had, while recently in Europe, some important interviews with the proprietors of the magnesite quarries in the west with regard to the introduction of that material into the United States. If your material should prove to be aluminates you could easily compete with them."

Markets.—The processes by which bauxite is manufactured are in some cases patented and the parties owning the patents are alone entitled to use or to dispose of them; in other cases the processes are guarded as trade secrets. Partly for these reasons and partly because the utilization of bauxite is confined to but few companies, the public knows but little of the uses to which the raw materials are put, or of the processes employed in their manufacture.

One thing that has thus far prevented the Arkansas bauxite getting into the market is the fact that the samples sent away have been selected without a knowledge of the composition required or of the material sent. As has been stated, iron, silica, and titanium are the objectionable ingredients, and the percentages of these cannot be determined by simple inspection, though familiarity with analyses of types will enable one to form an opinion of value on this subject.

Another matter of importance is that the freight rates charged by the railways out of Little Rock are so high as to prevent its profitable shipment.

Still another is that extravagant ideas of the value of the ore have induced those who would otherwise have done the mining and shipping to expect very large profits from it. As a matter of fact the value of bauxite at the place of production in the United States during the year 1895 averaged about four dollars[1]

[1] Engineering and Mining Journal, Jan. 2, 1897, 3.

a ton. The question for owners and miners is whether the market price will leave them a resonable margin of profit. The cost of plants for the utilization of bauxite is so great, and the local market for manufactured products so small, that, in my opinion, it is useless to think of factories being established in Arkansas. The factories are all in the north,[1] and the probabilities are that they will remain there for some years at least. In the meantime, if the bauxite beds are to be utilized, the material must be mined and transported cheaply. Labor and teaming are low, but railway freights are high at present. This necessarily prevents Arkansas' competition with the Georgia and Alabama deposits. It is to be hoped that the railways may see their way to offering rates that will allow of bauxite mining in Arkansas.

BIBLIOGRAPHY OF BAUXITE.

ANONYMOUS: Bauxite in puddling furnace. Iron and Steel Institute, 1882, I, 304–305.

AUDOIN and GAUDIN: Notizblatt des deut. Vereins f. Fabr. etc., V, 446.

AUGÉ: Note sur la bauxite, son origine, son âge et son importance géologique. Bul. Soc. Géol. de France, 3me sér. 1888, XVI, 345–350.

BAUER, MAX: Lehrbuch der Mineralogie, 1886, 353.

BERTHIER, R: Analyse de l'alumine hydratée des Baux, département des Bouches-du-Rhône. Annales des Mines, 2me sér. 1821, VI, 531.

BISCHOF, C.: Analysis of bauxite. The Metallurgical Review, 1878, II, 523. Abstr. Berg- u. Hüttenmännische Zeitung, 1878, 196.

———: Die feuerfesten Thone, Leipzig, 1876, 193–195.

———: Dingler's Poly. Journal 1881, B, 239, 469.

BLACKWELL, G. G.: (Bauxite), Trans. Manchester Geol. Soc. 1894, XXII, 525–527.

BLAKE, W. P.: Alunogen and bauxite of New Mexico. Trans. Am. Inst. Min. Engs. 1894, XXIV, 571–573. Abst. Amer. Geol. Sept. 1894, XIV, 196.

BRANNER, J. C.: Preliminary report to the governor of Arkansas on bauxite and kaolin. Arkansas Gazette and Arkansas Democrat, Little Rock, Jan. 8, 1891.

———: (Bauxites of Arkansas). Third biennial report, Bureau of Mines, Manufactures, and Agriculture of the state of Arkansas for 1893 and 1894, Little Rock, 1894, 119–125; also fourth biennial report of same, Little Rock, 1896, 105–110.

———: Bauxite in Arkansas. Amer. Geologist, March 1891. Abst. Eng. and Min. Jour., New York, Jan. 24, 1891, 114; Trans. Federated Inst. Min. Engs. III, 1057; Jour. Iron and Steel Institute, 1891, I, 275. Science, XVII, 1891, 17.

[1] The Pennsylvania Salt Company, Natrona, Pa. The Solvay Process Company, Syracuse, N. Y. The Pittsburg Reduction Company, Pittsburg, Pa.

BREWER, W. M.: The Warwhoop bauxite bank, Alabama, Eng. Mg. Jour. 1893, LV, 461.

COLE, G. A. J.: The rhyolites of the County Antrim (Ireland) with a note on bauxite. Sci. Trans. Roy. Dublin Soc., ser. II, 1896, VI, 105–109.

COLLOT L.: Age de la bauxite dans le sud-est de la France. Compt. Rendus 1887, CIV, 127–130. Abstract Neues Jahrb. f. Min. 1888, I, 452.

———: Age des bauxites du sud-est de la France. Bull. Soc. Géol. de France, 3me sér. XV, 331–345. Abstr. Trans. North of Eng. Inst. Min. Eng. 1888, XXXVII, 4.

———: Sur la bauxite d'Olliéres. Description géologique des environs d'Aix en Province, 1880, 84

COQUAND: Sur les bauxites de la chaine des Alpines (Bouches-du-Rhône) et leur âge géologique. Bull. Soc. Géol. de France, 2me sér. 1870–1, XXVIII, 98–115. Abstr. Neues Jahrb. für Min. 1871, 940–941. Jahresbericht der Chem. 1871, 1144.

D'AOUST, VIRLET: De la formation des oolithes et des masses nodulaires en général. Bull. Soc. Géol. de France, 2me sér. 1857–8, XV, 187–205.

———: Sur le minéral de fer alumineux pisolithique de Mouriès, dit aussi des Baux. Bull. Soc. Géol. de France, 2me sér. 1864–5, XXII, 418–420.

DAUBRÉE, A.: Sur l'existence de gisements de bauxite dans les départements de l'Hérault et de l'Ariége. Bull. Soc. Géol. de France, 2me sér. 1868–9, XXVI, 915–918.

———: Note sur un silicate alumineux hydraté, deposé par la source thermale de Saint-Honoré (Nièvre) depuis l'époque romaine. Comptes Rendus, 1876, LXXXIII, 421.

———: Les eaux suterraines aux époques anciennes. Paris, 1887. (Bauxite, 96.)

DE LAUNAY: See Fuchs.

DAMOUR, A.: Note sur un hydrate d'alumine ferrugineuse trouvé dans l'ile d'Égine, Grèce. Bull. Soc. Géol. de France, 1864–5, XXII, 413–416.

DEVILLE, H. SAINTE-CLAIRE: De la présence de vanadium dans un minéral alumineux du Midi de la France. Ann. de Chimie et de Phys., 3me sér. 1861, LXI, 309–342.

———: Analyse d'une bauxite du Paradon. Ann. de Chim. et de Phys., 3me sér. LXI, 309. Abstr. Jahresbericht der Chemie, 1861, 980.

DIEULAFAIT: Les bauxites, leur âges, leur origine. Comptes Rendus, 1881, XCIII, 804–807.

DITTE, A.: Sur la préparation de l'alumine dans l'industrie. Comptes Rendus, CXVI, 509–510.

———: Préparation industrielle de l'alumine. Ann. Chim. et de Phys., 1893, XXX, 280–282.

DRECHSLER E.: Analyse des Bauxits aus der Wochein. Dingler's Pol. Jour. 1872, CCIII, 479–481.

EGLESTON, T.: (Refractory material). Iron and Steel Inst. 1877, II, 533–534.

FABRE, G.: Note sur les failles et fentes à bauxite dans les environs de Mende. Bull. Soc. Géol. de France, 1869–70, XXVII, 516–518.

FLECHNER, A.: Zeitschrift der geologischen Gesellschaft, 1866, XVIII, 181.

FUCHS, ED. ET DE LAUNAY, L.-: Traité des gites minéraux et métallifères. Paris, 1893, I, 595–599.

HAUER, F. VON: (Bauxit, Krain). Jahrb. der K. K. Geol. Reichsanstalt 1866, XVI, 457. Abstr. Jahresbericht der Chemie, 1866, 923.

HAYES, C. W.: Bauxite. Mineral Resources of U. S. 1893, 159–167. Washington, 1894.

——: Geological relations of the Southern Appalachian bauxite deposits, Trans. Amer. Inst. Min. Eng. 1894, XXIV, 243–254.

———: Bauxite. Sixteenth An. Rep. U. S. Geol. Survey for 1894–5, Part III, 547–597. Washington, 1895.

HEINTZ: (Analysis). Stahl u. Eisen VII, 430; Journ. Iron and Steel Inst. II, 1887, 281.

HUNT, A. E.: Bauxite. (Discussion.) Trans. Amer. Inst. Min. Eng. 1894, XXIV. 855–861.

———: The properties, uses, and. processes of production of aluminum. Technology Quarterly, 1891, IV, 1–35. (Bauxite 20.)

JANNETTAZ, ED.: La composition d'une variété pisolithique de bauxite. Bull. Soc. Géol. de France, 1877–8, VI, 392.

———: Gibbsite et beauxite de la Guayane française. Bull. Soc. Min. de France, I, 70–71, Paris, 1879.

JOHN, K.: Verh. Geol. Reichsanstalt, 1874, 289; abstr. Jahresbericht der Chemie, 1874, 1246.

LANG, J.: Ueber Bauxit von Langsdorf. Bericht der Deutschen Chemischen Gesell., XVII, 1884, 2892–2894. Abstr Neues Jahrb. f. Min., 1886, II, 342. Abstr. Jour. Iron and Steel Inst., I, 1886, 293.

LAUR, F.: The Bauxites; a study of a new mineralogical family. Trans. Amer. Inst. Min. Eng., 1894, XXV, 234–242.

LENCAUCHEZ: (Dephosphorizing iron by bauxite) Société des Ingénieurs Civils. Abstr. Iron and Steel Institute, 1880, I, 334–335.

LIEBRICH, A. VON: (Bauxite). Zeitschr. für Kryst. u. Mineral., XXIII, 296.

———: Bauxit. Bericht der Oberhess. Gesellschaft für Natur.- u. Heilkunde, XXVIII, 57–98.

———: Beitrag zur Kenntniss des Bauxits vom Vogelsberge. Giessen, 1892.

MCCALLEY, H.: Alabama bauxite. Proc. Ala. Indust. and Scientific Society, 1892, II, 20–32.

———: Bauxite mining. Science, Jan. 19, 1894, 29–30.

———: Bauxite. The Mineral Industry, 1893, II, 57–68, N. Y. 1894. Abstr. Jour. Iron and Steel Inst., II, 1894, 303.

MEUNIER, S.: Sur l'existence de la bauxite à la Guayane française. Comptes Rendus, 1872, LXXIV, 633–634. Abstr. Jahresbericht der Chemie, 1872, 1099.

———: Sur l'origine et le mode de formation de la bauxite et du fer en grains. Compt. Rend. 1883, XCVI, 1737–1740.

———: Réponse à des observations de M. Augé et de M. A. de Grossouvre sur l'histoire de la bauxite et des minérals siderolithiques. Bull. Soc. Géol. de France, 1889, XVII. 64–67.

MIERZINSKI, DR.: Die Fabrication des Aluminiums. Vienna, 1885.

MINET, A.: L'Aluminium; fabrication, emploi, alliages. Paris, 1893.

NICHOLS, EDWARD: An aluminium ore. Trans. Amer. Inst. Min. Eng., XVI, 905–906. Abstr. Iron and Steel Inst. 1888, II, 228–229.

PACKARD, R. L.: Aluminum. Sixteenth Ann. Rep. U. S. Geol. Survey, Part III, Bauxite, 542–544. Washington, 1895.

PERCY, JOHN: Metallurgy. London, 1875. (Bauxite, 130–133.)

PETERSEN, TH.: Ueber den Anamesit von Rudigheim bei Hanau und dessen bauxitische Zersetzungsproducte. Jahresbericht d. Phys. Ver. zu Frankfurt a. M., 1891–2, 10.

———: Ueber Bauxitbildung (Bei. d. XXVII. Vers. d. Oberrhein. Geol. Ver. 2 S. 1893). Abstr. Neues Jahrb. f. Min., 1894, Ref. 460.

PRZIWOZNIK, E.: (Analyses of bauxites) Berg- u. Hüttenmännisches Jahrb. der k. k. Bergakad., XXXVIII, 415–416; XL, 564.

RICHARDS, J. W.: Aluminum: its history, etc. Philadelphia, 2d ed. 1890. Bauxite, 47–49, 88, 109–115.

ROTH, J.: Allgemeine u. chemische Geologie. Berlin, 1879. (Bauxite, I, 141, 142, 557.)

ROTH, LUDW.: Der Bauxit u. seine Verwendung zur Herstellung von Cement aus Hochofenschlacke. Wetzlar, 1882.

ROULÉ, LOUIS: Sur les gisements et l'âge de la bauxite dans le sud-est de la France. Compt. Rend., 1887, CIV, 383–385. Abstr. Neues Jahrb. für Min., 1888, I, 452.

———: Recherches sur le terrain fluvio-lacustre inférieur de Provence. Ann. des Sciences Geol. XVIII, 1885, 138; abstr. Neues Jahrb. für Mineral., I, 1887, 98–100.

SAEMANN: (Sur la bauxite des Baux) Bull. Soc. Géol. de France, 2me sér. XXII, 416–417.

SCHNITZER, GUIDO: (Analysis) Dingl. Poly. Jour. 184, 329. Chem. Centrb., 1868, 32. Jahresbericht der Chemie 1867, 981.

SCHWARTZ: (Analyses of bauxite) Dingler's Poly. Jour. V, 198, 156. Jahresbericht der Chemie, 1870, 1133–1134. Chem. Centrb., 1870, 740.

SEGER, H.: Zusammensetzung von Bauxit aus Irland. Dingler's Poly. Jour. 1880, CCXXIV, 334.

SENA, J. DA COSTA: Note sur hydrargillite des environs d'Ouro Preto (Brézil). Bull. Soc. Min. de France, 1885, VII, 220–222.

SIEMENS, C. WM.: The scientific works of C. Wm. Siemens. Vol. I, Heat and Metallurgy. London, 1889 (Bauxite in the manufacture of iron and steel, 296–298, 304, 217, 218.

———: (Furnace lining) Iron and Steel Inst. 1879, I, 153–155.

SIMMERBACH, B.: Glükauf, XXXI, 234–236; 251–252. Abstr. Iron and Steel Inst., 1895, II, 397.

SPENCER, J. W.: Geol. Sur. of Georgia; the palæozoic group. Atlanta, 1893, 210–230.

———: How aluminum is obtained from its ores. Science, February 16, 1894 XXXIII, 89.

STOLZEL, E.: Gewinnung der Metalle (aluminum from bauxites), Vol. II, 1591 Bolley's Handbuch der chemischen Technologie. Braunschweig, 1863–1886.

SUTHERLAND, JAMES: The preparation of aluminum from bauxite. Eng. and Min. Jour., October 3, 1896. LII, 320–322.

SYMES, R. G.: Memoir to accompany sheets 7 and 8 of the maps of the Geol. Survey of Ireland. Bauxite 24; mem. to sheet 14, p. 21; mem. to sheet 20, pp. 12 and 29.

TISSIER, CH. ET ALEX.: Guide pratique de la récherche de l'extraction et de la fabrication de l'aluminium et des métaux alcalins. Paris, 1863.

WAGNER, R.: Handbook of Chemical Technology. New York, 1889. (Aluminum from bauxite, p. 113; alum from bauxite, 259–260.

———: Ueber die Bedeutung des Bauxits für die chemische Industrie. Berg- u. Hüttenmännische Zeitung, 1865, 264. Kunst- u. Gewerbeblatt, 1865, 68. Deutsch. Industrie-Zeitung, 1865, 113, 125. Wagner's Jahresbericht über die Fortschritte der chem. Tech, 1865, XI, 323–336. Moniteur Scientifique, 1865, 343.

WEDDING: Notiz über den Beauxit (Niederrhein. Gesellsch. für Natur- u. Heil kunde zu Bonn. Sitzg. V. 8. April, 1863. Abstr. Neues Jahrb. für Min. 1863, 723.

WILLIAMS, C. H.: (Bauxite) Trans. Manchester Geol. Soc. XXII, 521.

WILLIAMS, J. F.: (Age, origin and distribution of Ark. bauxite) Igneous rocks of Ark. Little Rock, 1891, 124–125. Maps II and III.

WILL, W.: Bericht der Oberhess. Gesellschaft für Natur- u. Heilkunde. 1883 XXII, 314.

———: Revue Universelle des Mines et de la Métallurgie No. 2, IX, 1881 (on bauxite in dephosphorization of iron). Abstr. Iron and Steel Inst. I, 1881, 331–332.

J. C. BRANNER.

STANFORD UNIVERSITY.

EDITORIAL.

As THE time for the meeting of the International Congress of Geologists approaches interest in the series of events connected with it increases. The several circulars that have been issued have made evident the extent of the preparations that are being made at St. Petersburg and the largeness of the generosity of His Majesty the Emperor of Russia. Opportunity has been offered for all geologists taking part in the congress to visit many of the most important regions of Russia, presenting widely different geological phenomena — the crystalline rocks of Finland and the glacial phenomena in the north; the vast expanse of slightly disturbed and little-altered Palæozoic strata in the central portion of the country; the far-famed mining districts of the Urals, and the grand scenery and varied features of the Caucasus and of Transcaucasia. Seldom may geologists have such an opportunity to contrast within the brief period of a few weeks the forest-clad, moist north lands with the barren, arid regions of the south, or experience in quick succession the sensations produced by the boundless horizon of the steppes and by the deep gorges and lofty summits of the Caucasian Alps.

***

THE liberality of the Czar in presenting the geologists with first-class tickets over all the railroads under Russian control is an act of hospitality fitting the ruler of so great an empire, and one fully appreciated by the geologists of all parts of the world. That it should have been accepted by many who would not otherwise have been able to travel so extensively was to have been expected. And it is not surprising to hear that many persons not having claims to the title of geologists have applied for the privileges, to the embarrassment of those in charge of the

management of the great excursion. It is proper that a scrutiny of the lists of applicants should be undertaken for the purpose of limiting the numbers to those who are actually geological workers or teachers of the science, and who will derive the most benefit from the instruction which will be given by the geologists acting as leaders of the several excursions. It would be unfortunate if, by the presence of many untrained excursionists, the object of the expeditions should be defeated. It is reasonable, then, that the committee in charge at St. Petersburg should propose to test the geological knowledge of all those wishing to join the excursions, when their attainments in the science of geology is not already known. We understand that those not known to the committee to be geologists will be required to pass an examination in various branches of geology before being permitted to take part in the excursions.

***

A RECENT circular from St. Petersburg calls attention to the fact that there was established at the London congress a permanent committee that should have charge of the selection and elaboration of questions to be submitted to each subsequent session, as well as of the preparation of reports relating to such questions. After citing the report of the committee relative to the unification of stratigraphical nomenclature, and after noting the fact that the matter received no attention at the Washington and Zurich meetings, the committee of organization at St. Petersburg suggests that the question of the general principles involved in any stratigraphical classification be discussed, first, as to whether it be *artificial*, based solely on historical data, or *natural*, based as well on general physiographic changes as on faunal data; second, as to laws that should govern the introduction of new terms into stratigraphical nomenclature. It is also suggested that the principles that should govern petrographical nomenclature ought also to be considered.

The confusion in these nomenclatures which is constantly increasing owing to rapid accession of new facts and to lack of

system in the creation of new terms makes apparent the need of some organization of terms and of the establishment of some general principles of nomenclature. The committee, realizing the magnitude of the undertaking and the shortness of the time of a single session of the congress, nevertheless expresses the hope that enough may be accomplished at the coming session to lead to the satisfactory solution of these problems. Certainly the discussion of the more general and fundamental principles of nomenclature by which a common usage of terms may be brought about is the proper function of an international congress of geologists, and it is to be hoped that the proceedings of the coming session may be along these lines. J. P. I.

REVIEWS.

SOME RECENT PAPERS ON THE INFLUENCE OF GRANITIC INTRUSIONS UPON THE DEVELOPMENT OF CRYSTALLINE SCHISTS.

MICHEL-LÉVY: *Contribution à l'étude du Granite de Flamanville et des Granites Français en général.* Bull. des Services de la carte géol. de la France, No. 36. Paris, 1893, pp. 41.

L. DUPARC and L. MRAZEC: *Nouvelles Recherches sur le massif du Mont-Blanc.* Archives des Sciences Physiques et Naturelles. Tome XXXIV, 1895, pp. 39.

L. DUPARC: *Le Mont-Blanc au point de vue géologique et pétrographique. Ibid.* 1896, pp. 8.

J. VALLOT and L. DUPARC: *Sur un Synclinal schisteux ancien formant le coeur du massif du Mont-Blanc.* Comptes Rendus des Séances de l'Académie des Sciences. Paris, Mars 1896, pp. 3.

J. HORNE and E. GREENLY: *On Foliated Granites and their relation to the Crystalline Schists in Eastern Sutherland.* Quarterly Journal of the Geological Society. London, Vol. LII, 1896.

A. SAUER: *Geologische Specialkarte des Grossherzogthums Baden.* Erläuterungen zu Blatt Gengenbach. Heidelberg, 1894, pp. 87.

A. SAUER: *Ibid.* Erläuterungen zu Blatt Oberwolfach-Schenkenzell. Heidelberg, 1895, pp. 76.

F. SCHALCH: *Ibid.* Erläuterungen zu Blatt Petersthal-Reichenbach. Heidelberg, 1895, pp. 82.

A. ANDREÆ and A. OSANN: *Ibid.* Erläuterungen zu Blatt Heidelberg. Heidelberg, 1896, pp. 60.

G. KLEMM: *Beitrage zur Kenntniss des krystallinen Grundgebirges im Spessart.* Abh. der Gross. Hessischen Geologischen Landesanstalt zu Darmstadt. 1895, pp. 87.

In one of the oldest and best known of the German universities there is delivered annually a very able and exhaustive course of lectures on petrography, in which no less than fourteen lectures are devoted to a presentation of our knowledge of the single rock, granite, but it is

nevertheless somewhat depressing to consider on how many important questions connected with this, the most common and ordinary of all the plutonic rocks, there are still grave differences of opinion among those justly considered as authorities. Thus all do not agree even as to the order of the crystallization of the constituents of the rock, some holding that there are two generations and others that there is but one, while again a marked difference of opinion exists concerning the effects produced by granite upon the rocks through which it is intruded.

As the result of a whole series of careful studies on various contact zones, chiefly in Germany, Austria, and Scandinavia, it is commonly believed in these countries that the granite magma, by its heat, pressure and escaping vapors, causes a recrystallization of the country rock, the process being one of diagenesis, the granite giving nothing to the rock through which it breaks, except in places, perhaps, a small amount of boracic acid.

In France, however, and everywhere within the French "sphere of influence" different opinions prevail, and it would actually appear from the studies made in these parts of Europe that the laws of nature changed upon crossing the political boundaries. Contact zones have been described by Barrois, Michel-Lévy, Delage, and other French petrographers, in which the country rock adjacent to the granite has become completely "granitized" by the transfusion of granitic material into it, and in a well-known paper by Michel-Lévy, which appeared in 1887,[1] he stated it as his belief that by this process gneisses, leptynites, dolomitic schists and amphibolites, indistinguishable from those of the Archaean, are produced, and that in fact the so-called primitive rocks have really originated in this way, by the intrusion of igneous rocks into clastic sediments, which sediments have undergone a profound metamorphosis with the addition of an immense mass of material, the process being essentially one of a metasomatosis.

In the first section of the Bulletin, whose title is given above, Michel-Lévy describes an additional contact zone of this kind occurring about the granite of Flamanville, which granite cuts shales, sandstones, and quartzites, chiefly of Silurian and Devonian Age. On approaching the granite the shales present successively the usual zones of the spotted clay slate, micaceous clay slate, and hornstone, but in the vicinity of the actual contact they are broken up, eaten into, and partially dis-

[1] Sur l'origine des terrains cristallins primitifs. Bull. Soc. Géol. de France, 3me s., xv, 1887, 103.

solved by the granite, which holds many inclusions and also injects itself into the rock in narrow veins—*lit par lit*—along its plains of lamination or foliation, altering it intensely and at the same time giving to it a granitic character. In the second half of the Bulletin the author presents some observations on granites in general, more especially in relation to their contact effects, reaffirming and somewhat enlarging upon the views put forward by him in 1887. He holds that the conclusions arrived at by Rosenbusch and commonly held by petrographers, that feldspar is not usually produced in contact zones except in comparatively small amount by the diagenesis of the altered rock, and that there is no transfusion of granitic material into the invaded rock, although true of the individual contact zones investigated, are not true of contact zones in general, but that there is frequently developed immediately along the contact a zone in which an intimate admixture of the granitic material with that of the injected rock is a dominant characteristic. This admixture is brought about in part by the injection of the granite in thin layers—*lit par lit*—into the stratified rock parallel to its lamination, in part by a transfusion in some obscure way by means of mineralizing solutions of the elements of quartz and feldspar through the schists, causing these minerals to crystallize out through the substance of the altered rock, and in part by the actual solution of the injected rock in the granite magma. In this zone, which in ordinary granite intrusions is usually but a few yards in width, there can be found all the rocks characteristic of the great regions of crystalline schists—mica schists, granulites, gneisses, amphibolites, etc., formed by the action of the granite on the ordinary sedimentary strata of the earth's crust.

This zone, moreover, although often narrow as exposed, where the deeper seated parts of the "appareils granitiques" are laid bare to our study by the process of denudation, is found to become much wider and often of great stratigraphical importance. Barrois is cited as having found in Brittany cases where there has been an undoubted transformation of whole districts of Cambrian schists into gneiss by the process of "granitization" above referred to, it being possible to follow bands of quartzite which resist the general "feldspathization" from the margin of the area into parts of the district where the associated schists have been completely transformed into gneiss.

The work of Duparc and Mrazec, on the massiv of Mont Blanc is also cited as affording conclusive demonstration of similar transforma-

tion, while the gneissic zone about the granulite of the Saxon Granulitgebirge is cited as another case in point. It is believed that the granite magma first rises along lines of fracture in the crust. Its presence leads to a heating of the rock into which it is injected, and its intrusion is accompanied by a "*circulation intense*" of mineralizing fluids, probably rich in alkalis. These produce at first a transference of quartz from one part of the mass to another and the development of biotite, which is a marked feature in contact zones. Then follows "feldspathization," which commences by the development of little strings of quartz and feldspar following for the most part the schistosity of the invaded rock, and which grow in size until the whole mass of the schist is transformed into granite, the texture of the schist being broken down and its elements set in motion to form with the transfused material new combinations. The granitic magma or emanations thus slowly dissolve, alter or incorporate, whichever we may choose to call it, the wall rock, transforming it first into a gneiss, then into a gneissic granite, and finally into a granite. The original intrusion thus slowly enlarges its boundaries and increases its volume.

This process, we are told, is at work wherever granitic magmas come in contact with clastic rocks in the deeper parts of the earth's crust, and it is thus that, as before mentioned, the crystalline schists are produced. The granite does not therefore, as Suess has supposed, fill great cavities in the earth's crust which have been produced by tangential stresses, thus giving rise to batholites, but starting from some line of fracture eats its way into the surrounding rocks and develops itself largely at their expense in the way above described.

According to Professor Duparc and his associates, this process of granitization plays a very important rôle in the development of the crystalline rocks of the Mont Blanc massiv. This massiv has usually been considered as composed of protogine, that is of a somewhat altered granite, massive in the center and progressively more gneissic or schistose as the outer portions are approached, the whole enveloped by a mantle of mica schists. These mica schists contain bands of amphibolite, eclogite, and other similar rocks found in corresponding positions about other protogine masses elsewhere in the Alps.

Messrs. Vallet and Duparc have however found that the central part of the massiv is composed largely of various micaceous gneisses and crystalline schists, associated with and invaded by the protogine and even passing into a protogine gneiss. Some of these included rocks

are very basic and cannot therefore, it is thought by the authors, be in any way considered to be derived from the protogine by dynamic action, but are to be considered as sediments, depressed by a synclinal fold and bounded by the protogine on either side. The whole series of rocks, both protogine and surrounding schists, are penetrated by a series of more recent granite veins or dykes, and these it is believed have brought about the profound metamorphism of the surrounding rocks, injecting and "granitizing the schists everywhere in the vicinity of the protogine, so that the gneissic zone which immediately borders the protogine is not in any way connected, genetically, with the protogine itself, but results from the profound alteration of the mica schists surrounding the protogine by these newer granite dykes. The varying character of the different schistose rocks in this gneissic zone is considered to be due to the varying resistance offered to this "granitizing" action by the different beds in question. Thus, for instance, the eclogites retain their basic character and have not been transformed into orthoclase gneiss, because they are too compact to allow of a free circulation through them of the solutions producing the alteration. In the paper by Duparc and Mrazec, a number of analyses of the several varieties of protogine and granitized schists are given.

The crystalline schists of eastern Sutherland, described by Messrs. Horne and Greenly, consist of a series of gneisses, granulites, mica schists, etc., some few members of which show conclusive evidence of a sedimentary origin while the origin of others is doubtful. The whole series has been intensely deformed. Not a cubic inch can be found which has not suffered deformation, but distinct cataclastic structure is not seen, so that recrystallization must have taken place during or after the movements. The series is invaded by masses of intrusive granite, which have broken across the schists, anastomozing through them and often penetrating them as a series of thin leaves, parallel to their foliation, in the manner termed by the French writers *lit par lit* injection. The boundary between the injecting granites and the schistose series is often rather ill-defined, owing to the fact that the granitic constituents seem to interlock with those of the wall rock with which they are in contact. The granite never shows any finer grained sahlband, indicating injection to a cold rock, but is usually coarse-grained and pegmatitic on the borders. It seems reasonable to infer, therefore, that the igneous material was introduced when earth movements were in progress and when the country rock was at a high temperature.

On approaching large masses of granite, the schistose series becomes more highly altered, sillimanite and other contact minerals making their appearance, but the invaded rocks often take upon themselves a character so closely resembling that of the invading granite as to "amalgamate the two rocks into one great gneissose complex." Thus the foliation of the invading granite, which can often be seen to be parallel to that of the invaded gneisses, is in many cases certainly due to the biotite foliæ of the latter, having retained their original position, while the associated "quartzo-feldspathic elements have been incorporated with those of the granite," as every gradation can be traced from inclusions retaining their natural orientation to the merest trains of mica flakes in a granitic rock. In other cases, however, the foliation of the invading granite does not coincide with that of the invaded gneiss but cuts it. Powerful movements were the "initial cause of the whole series of phenomena. . . . . With regard to the granites, it is difficult to believe that they are wholly foreign matter; though here it is necessary to observe the utmost caution, the chemical difficulties being so great." Although Messrs. Horne and Greenly are guarded in their statements, their studies being rather general in character, it is clear that they believe the processes at work to be very similar, if not identical with, those described by Michel-Lévy and Duparc.

The views put forward in these papers lead us back to the time of Hutton, who, in his *Theory of the Earth* states that the kind of granite which shows banding and foliation is probably an altered sediment, the foliation being a survival of the bedding of the original rock. This fact, however, does not by any means discredit the view as many of Hutton's opinions after long neglect have finally proved to be correct. The views also have certain features in common with the crenitic hypothesis of Hunt. The whole process is, however, very recondite and mysterious in character.

One of the great difficulties in the way of the acceptance of these views is the absence of chemical proof. In those contact zones on which accurate chemical work has been done, it has been shown that no considerable transference of material has taken place. In these other cases where this enormous transference of material is assumed, no accurate chemical work seems to have been carried out to support the contentions. In Duparc's work, as has been mentioned, a number of analyses of various normal and "granitized" rocks are given, but

no attempt is made to follow out the changes undergone by a single bed, and it is impossible to make out in how far the differences in composition shown to exist, are primary differences in the composition of the rocks analyzed. The chemical evidence adduced is, therefore, by no means conclusive. The question also arises as to the ultimate source of the enormous amounts of silica and alkalis required for the conversion of hundreds of cubic miles of the miscellaneous rocks of a sedimentary system into granite.

It is furthermore a question as to how far dynamic action is responsible for many of the phenomena described. When, for instance, a schist is shattered and granite is intruded into the cracks and fissures, masses of the invaded rock being found scattered through the granite, and, after cooling, the whole complex is stretched or rolled out by dynamic movements, as is usually the case in districts where crystalline schists occur, the injected arms of the granite, great and small, become pulled apart and eventually appear as little discontinuous strings and lumps of quartz and feldspar in the enclosing schists, following the line of movement, while a schistose structure parallel to these strings is given to the whole rock by the same movements.

In certain parts of the Laurentian of Canada, schists and gneisses are found full of such strings and lumps of quartz and feldspar, presenting exactly the characters described by the French petrographers as resulting from the granitization of sedimentary rocks. The Canadian rocks, however, have undoubtedly been produced in the way just described, every possible transition from the massive injection to the foliated complex being observed in a hundred different cases. In the Lepontine Alps, moreover, to the east of Mont Blanc, where the *Schieferhülle* of the several protogine masses have been very carefully studied by Heim, Schmidt, and many other observers, the phenomena attributed to "granitization" by Duparc are everywhere considered to be the results of crushing under the influence of such movements, with, in certain cases, the infiltration of secondary cracks and rifts by materials deposited from ordinary terrestrial waters, which in such positions would probably be more or less heated. Even in the Saxon Granulitgebirge, cited by Michel-Lévy as a case where transference of material could be distinctly observed, and where certainly the granulite does seem to have eaten its way into the schists, only however for a short distance back from the immediate contact, the appearance presented bearing a striking resemblance to that, very familiar to the tyro

in assaying, when his slag being too basic has eaten its way into the clay crucible appearing when the crucible is broken through its substance here and there in spots and streaks; Lehmann, who has made a most exhaustive study of the whole region points to the fact that this zone is not always present, and states it to be his belief that the granitic material forming the *flammen* in the schist has not been derived from the granulite magma, but is due to the deposition of the granitic material in spaces formed by the separation of the foliæ of the schist, under the great stresses to which the region has been subjected, the granitic material in question having been derived from later intrusions which elsewhere can be clearly seen to cut the granulite. From personal observation, however, I must say that appearances are strongly in favor of Naumann's view, that along the narrow zone of the immediate contact the granulite magma has eaten into the schist to a certain distance, a phenomenon which is quite intelligible and perhaps in certain cases to be expected, but which is quite distinct from the wholesale transformation of the schist into granite by the mysterious process of "granitization."

In how far this process of transfusion which is considered by Michel-Lévy and other French geologists to play so important a part in the origin of the crystalline schists is really active, must be determined by detailed studies of the deeper seated granite contacts and of the so-called Archean areas in various parts of the world.

Such studies in the case of Archean areas are presented in the recent maps, with accompanying explanatory texts, issued by the geological survey of Baden, and whose titles are given above. This survey, following the lead of those of Prussia, Saxony, and Hessen, was constituted in 1888 for the purpose of mapping in detail the Grand Duchy of Baden, an area of 5843 square miles, on a scale of $\frac{1}{25000}$. For this purpose the territory in question has been divided into 170 sections. Work was begun in 1889 and maps of twelve sections have already been published. As about one-quarter of the Grand Duchy of Baden is underlain by *Grundgebirge* including the well-known area of the Black Forest, ample opportunity is given for a thorough study of these ancient rocks. Six of the maps already published are in areas of the Grundgebirge; of these three have been mapped by Dr. Sauer, to whom we are already indebted for his valuable contributions to our knowledge of the ancient crystalline rocks of Saxony. The maps are among the best which have yet appeared of any Archean region, and serve to

bring out clearly the complex relations of the several members of the system.

Two distinct classes of gneissic rocks are recognized in the areas examined, in addition to the numerous intrusions of igneous rocks of various kinds. To each of these classes a collective name has been assigned, taken from a locality where it is well exposed; the first being known as the Rensch Gneiss and the second as the Schapbach Gneiss. A few of the most notable varieties of each class of rock are distinguished in mapping, but no attempt is made to map separately the bewilderingly numerous and minute petrographical variations of the gneissic rocks attempted in the survey of Saxony. The Rensch gneisses consist chiefly of orthoclase, biotite, and quartz. The mica is usually abundant, and sillimanite is a characteristic accessory constituent, often occurring as a paramorph after andalusite. Garnet and sphene are seldom found. The rock often shows in the arrangement of the constituents a structure similar to that seen in the hornstones of contact zones. The presence of small lenticular segregations of quartz, or of quartz and orthoclase, scattered through the rock is also a characteristic feature of the gneisses of this class. Conformably interbanded with these Rensch gneisses are subordinate masses of quartz schist, graphitoid schists and gneisses, pyroxene gneisses and amphibolites.

The Schapbach gneisses are much more uniform in character, usually poorer in mica, and have a marked tendency to assume a granitic aspect, often passing over into granulites. Quartz lenses and fine-grained, highly quartzose bands are absent, but garnet and orthite are frequently present. The only inclusions found in the gneisses of this class consist of a gabbro-like amphibolite. The gneisses of the two classes sometimes seem to pass into one another along the contacts, but the distinction is usually sufficiently well marked to enable them to be properly separated in mapping.

Although no direct expression of opinion concerning the origin of these gneisses is given in the publications in question, it seems to be the opinion of the survey that the two classes probably differ in origin, the Rensch gneisses representing highly altered sediments and the Schapbach gneisses being of igneous origin. The chemical evidence afforded by a number of analyses of typical gneisses of each series which are given, tend to support this view as does also the structure of the rocks, and the character of the subordinate intercalated masses in

the case of the Rensch Gneiss. The evidence one way or the other will, however, be greatly extended as the mapping with concomitant chemical investigation progresses, and the Director of the survey, Professor Rosenbusch, evidently desires to await this further evidence before making any decided statements concerning the genetic relationships of the complex. If the Rensch gneisses prove to be altered sedimentary rocks their high content of feldspar and the presence in them everywhere of lenticular masses and strings of quartz and feldspar will certainly be cited by the French authorities as evidences of "granitization." But two questions remain to be decided — first, whether the high content in feldspar is not due to a high content of alkalis in the original sedimentary rocks, these having been perhaps of the nature of feldspathic sandstones, arkoses and greywackes, and secondly, whether the strings and lenses of quartz or quartz and feldspar do not fill spaces opened by the dynamic movements to which the rocks have been subjected, quite independent of any granitic intrusion. Whether in fact any mysterious cementation-like transfusion of granitic material through these rocks has really taken place. The detailed chemical work which is now being carried out will, when completed, undoubtedly decide whether the supposed altered sediments have or have not a composition which can be attributed to a sedimentary series.

A similar twofold origin is claimed by Klemm for the crystalline Grundebirge of the Spessart, although here the sedimentary portion is believed to be of late Palæozoic age and is possibly equivalent to a series of schistose hornstones, graphite schists and garnet rocks, quite distinct from the gneissic series of the Black Forest, which were found by Andreæ and Osann in the Odenwald to the north of Heidelberg.

These studies bearing upon the vexed question of the origin of the crystalline schists have at present an especial interest for petrographers in America, where such enormous areas of these rocks are now under investigation.

FRANK D. ADAMS.

Glaciers of North America, a Reading Lesson for Students in Geography and Geology. By ISRAEL C. RUSSELL. Boston: Ginn & Co., 1897.

The preparation of a work of this high grade by a busy university professor of large professional experience and demonstrated investigative ability, as a reading lesson for students of geography and

geology, is worthy of special note as one of the signs of the educational times. It is significant both as an indication of a demand and as exemplifying a supply. It is a gratifying mark of progress that there should have grown to be a place for a work of this character as a supplement to the usual treatises on geography and geology. It is a not less gratifying mark of progress that such a demand should be appreciated and met by a careful and competent scientist of high position.

The work opens with a clear and brief statement of the nature of glaciers, and of their varieties and of the work done by them. Their distribution in North America is then sketched comprehensively, after which individual glaciers and glacial districts are described in detail. It is in the study of these glaciers individually, aided by the numerous photographic illustrations, that the real characters of glaciers will come to be realized by the students. The average reader will doubtless be surprised at the number, variety and instructiveness of American glaciers. They very greatly surpass those of all other accessible continents.

Following the individual descriptions are chapters on the climatic changes indicated by the glaciers of North America, upon the cause and mode of glacial motion, and upon the life history of a glacier. The discussions of theoretical questions are conservative and judicial in tone, and manifest a notable tendency to eclectic conclusions. Professor Russell's comprehensive statement of the various hypotheses of glacial motion will doubtless be found one of the most interesting sections of the volume by advanced glacial students. The work is heartily commended to teachers and general readers as well as students.

T. C. C.

Former Extension of Cornell Glacier near the Southern end of Melville Bay. By RALPH S. TARR. Bull. Geol. Soc. Amer., Vol VIII, pp. 251–268. Plates XXV to XXIX, March 1897.

An abstract of this paper was given in the January-February number of this JOURNAL, pp. 95–96. An editorial relative to it appeared in the same number, pp. 81–85. Communications in reference to it have also appeared in *Science*, Vol. V, No. 113, February 26, p. 344; No. 114, March 5, pp. 400–401, and No. 117, March 26, pp. 515–516. This further notice is introduced mainly for the purpose of presenting

THE DEVIL'S THUMB

Elevation 2,650 feet; glaciated surface in the foreground; rugged angular topography in background on left. Transported pebbles obtained on crest of the Devil's Thumb. Photograph by J. O. Martin. (Author's legend.)

to the readers of the JOURNAL the chief photograph of the paper for comparison with those previously presented in this JOURNAL in the series entitled "Glacial Studies in Greenland." It need only be added that Professor Tarr regards this photograph as presenting a "rugged, angular topography," and offers it with similar photographs in sub-

FIG. 1. Dalrymple Island, an illustration of unglaciated topography.

stantiation of his claim that topographic contours cannot be trusted as indices of glaciation. As glaciation seems to the reviewer to be expressed with much clearness and definiteness in the contours of the promontory here cited as a proof to the contrary, it seems the fairest mode of review to reproduce the photograph and permit geologists to judge for themselves. For comparison there is added a photographic illustration of Dalrymple Island, which has been previously published in this JOURNAL as an illustration of unglaciated asperities. The reviewer does not see how anyone trained in glacial topography can fail to see glacial modification in the one and the absence of it in the other. The humorous feature of the issue raised in the paper and the outgrowing discussion is that contours of the type illustrated by Professor Tarr's photographs were identified as moderately glaciated by those whose conclusions he seeks to overthrow and his observa-

the Devil's Thumb. Angular topography in background on left. Transported pebbles obtained on crest of Photograph by J. O. Martin. (Author's legend.)

tions of the drift and other positive indices confirm the correctness of their identifications.

It is infelicitous to call the promontory in the photograph the Devil's Thumb. The author remarks in a footnote: "This is the Devil's Thumb as given on the Danish and British Admiralty charts.

FIG. 2. Devil's Thumb, S.E.^{b}E. (True) S.S.W.½W. (Mag^{c}.) (Legend on British Admiralty Chart.)

The real Devil's Thumb of the Arctic explorers is some forty or fifty miles north of this" (p. 254). The true Devil's Thumb is, however, sketched on the British Admiralty chart and the sketch there given is herewith reproduced. It is topographically an object of a very different order from the promontory of the photograph. As it has been cited in the articles in this JOURNAL in its bearings upon the limitations of glaciation, it seems unfortunate to introduce another Devil's Thumb of so different a nature. Confusion has already arisen by reason of this. An error in the location of the Devil's Thumb, in a region where the charts are confessedly inaccurate, does not seem to us to justify the transfer of the name to the false location.

The author makes passing mention of the driftless area in the Inglefield Gulf region, and although he declines to discuss it, as it was not seen by him, he remarks in a footnote that "he cannot let this opportunity pass without raising the query whether the topography in the neighborhood of the Greenland driftless area is not such that an area of this sort would naturally be expected. Was not the movement of the ice outward and the main stream down the Inglefield Gulf? And is not the driftless area located in the place where the high Red Cliff peninsula would naturally have clogged the ice and hence prevented its action of erosion and notable transportation?" The driftless area is part of the same ancient peneplain as the summit of the Red Cliff peninsula (JOUR. GEOL., pp. 205–206, Vol. III, 1895). It lies on the *east side of Red Cliff peninsula* (see map on p. 668, Vol. II, JOUR. GEOL.). It lies *between it and the great ice-cap*. It is separated from the peninsula by the valley of Bowdoin Bay about two miles wide and 2000 feet deep. How an isolated part of a peneplain can protect from glaciation another part of the same plain lying between

it and the source of the glacial motion, and several miles distant, is not easily understood. The suggestion does not seem to have sprung from a serious consideration of the conditions of the problem.

T. C. C.

Report on the Valley Regions of Alabama (Palæozoic Strata). Part I. On the Tennessee Valley Regions. By HENRY MCCALLEY.

The palæozoic area in northern Alabama may be divided into two regions. That to the northwest, drained chiefly by the Tennessee River and its tributaries, is characterized by the nearly horizontal and undisturbed condition of the strata. The region to the southeast, drained by the Coosa River, is a region of greater disturbance with the geologic features much complicated by the folding and faulting of the strata. The first of these regions is described in the present report; part two of the report, not yet published, will treat of the second or Coosa valley region.

The report is divided into two sections, the first of which is a general treatment of the physical features, geology, natural resources, soils, agricultural features, timber, waterpower, climate, rainfall, drainage, and health. Much the larger part of the report is devoted to the second section which treats of county details.

Chapter two of the first section entitled Geology describes the stratigraphy of the region and is the only portion of the report of general interest. The following table of formations is given:

(8) Tertiary	(k) Lafayette	
(7) Cretaceous	(j) Tuscaloosa	
(6) Carboniferous	(i) Coal Measures	200–500 feet
(5) Upper Sub-Carboniferous	(h) Bangor limestones,	200–450 feet
	(g) Hartselle sandstones	150–400 feet
(4) Lower Sub-Carboniferous	(f) Tuscumbia or St. Louis limestones	75–200 feet
	(e) Lauderdale or Keokuk chert	100–250 feet
(3) Devonian	(d) Black shale	0–45 feet
(2) Upper Silurian	(c) Red Mountain or Clinton (Niagara)	3–350 feet
(1) Lower Silurian	(b) Pelham or Trenton (Nashville,	700–1000 feet
	(a) Siliceous (Knox) dolomite and chert	2000 feet

The physical characters of each of these formations is briefly described, though no lists of fossils are given by which the faunas may be compared with those of the supposed equivalent strata elsewhere.

The remainder of the report will have its chief interest and usefulness among the local geologists of the region described.

STUART WELLER.

Final Report on the Geology of Minnesota. Palæontology. Vol. III, Part II. Minneapolis, Minn., 1897.

Part II of the *Palæontology of Minnesota*, a volume of about 600 pages, illustrated by forty-eight plates besides 133 figures, has just appeared. Like its companion volume, Part I, it treats only of the Ordovician fossils. Besides the introduction, which is a paper by N. H. Winchell and E. O. Ulrich upon "The Lower Silurian deposits of the Upper Mississippi province; a correlation of the strata with those in the Cincinnati, Tennessee, New York, and Canadian provinces, and the stratigraphic and geographic distribution of the fossils," the volume contains the following papers:

1. The Lower Silurian Lamellibranchiata of Minnesota. By E. O. Ulrich.
2. The Lower Silurian Ostracoda of Minnesota. By E. O. Ulrich.
3. The Lower Silurian Trilobites of Minnesota. By J. M. Clarke.
4. The Lower Silurian Cephalopoda of Minnesota. By J. M. Clarke.
5. The Lower Silurian Gastropoda of Minnesota. By E. O. Ulrich and W. H. Scofield.

The first three of these papers were published separately in small editions and distributed during the period from June 16, 1894, to September 27, 1894. The last two papers appear for the first time with the publication of the complete volume.

The volume supplies a long-felt want to students of the Ordovician faunas of the West, and will doubtless be the standard work upon these faunas in the Mississippi region for many years. The author of the chapters upon the Lamellibranchiata and Gastropoda should perhaps have been more conservative in establishing new genera and species; however the classification of the greater number of the classes of organisms abundantly preserved as fossils in the palæozoic rocks, is at present in a transition state, and any attempt to make more natural, and to give more definiteness to their classification is a step in advance.

STUART WELLER.

Bulletins of American Palæontology. Vol. I. Published by Professor G. D. Harris, Ithaca, N. Y.

The publication of a purely palæontological bulletin has been undertaken by Professor G. D. Harris, of Cornell University, and the first volume has just been completed. The undertaking of Professor Harris is truly a commendable one, and should receive the encouragement of American palæontologists. Heretofore palæontology has had, in America, no organ of publication purely its own. The literature of the subject has been scattered through a score or more of proceedings or transactions of learned societies and periodicals. If, from now on, Professor Harris' bulletin meets with the coöperation of American investigators which it deserves, our literature will become more concentrated and consequently much more accessible.

The bulletin appears, not at stated intervals, but at such times as material may be ready for publication. Volume I consists of five numbers, which have appeared at intervals since May 25, 1895.

1. "Claiborne Fossils," by G. D. Harris. Pp. 1–52. Plate I. (May 25, 1895.)

Part I of this bulletin is a "Synonymy of the Claiborne sand species of Conrad and Lea, as determined by an inspection of the type collections now at the Academy of Science of Philadelphia." This paper will be welcome to all students of the Eocene faunas of eastern America. The description of species from the Claiborne sands by the two authors, Conrad and Lea, during the same period of time, and without the slightest recognition on the part of either of the work being done by the other, brought about a most confusing state of synonymy. Professor Harris has straightened out this confusion by an inspection and comparison of the type specimens of both authors.

Part II of the bulletin is a description of six new species from the Claiborne sand.

2. "New or little known Tertiary Mollusca from Alabama and Texas," by T. H. Aldrich. Pp. 53–82. Plates II–VI. (June 24, 1895.)

3. "Neocene Mollusca of Texas, or fossils from the deep well at Galveston," by G. D. Harris. Pp. 83–114. Plates VII–X. December 2, 1895.)

This paper was noticed in this Journal, Vol. IV, p. 126, and needs no further comment.

4. "The Midway Stage," by G. D. Harris. Pp. 115–270. Plates XI–XXV. (June 11, 1896.)

In this paper it is shown that between the basal Eocene deposits, or Midway Stage, and the uppermost Cretaceous, there is in the southern states a decided break, both stratigraphic and faunal, so that not a single species is known certainly to have crossed from one formation to the other. These initial beds of the Eocene are treated both geologically and faunally by Professor Harris. The field investigations were carred on in the states of Texas, Arkansas, Tennessee, Mississippi, Alabama, and Georgia. From his studies Professor Harris is led to believe that a considerable time interval elapsed between the close of the Cretaceous deposition and the beginning of the Eocene deposition in the Mississippi basin, and that wherever good contact exposures are found, there may be found, on careful study, ample evidence of nonconformity.

This initial Eocene fauna is discussed at length, all the old species of Mollusca and many new ones are described and figured.

5. "A reprint of the palæontological writings of Thomas Say; with an introduction, by G. D. Harris. Pp. 271–354. Plates XXVI–XXXII. (December 7, 1896.)

The republication of these papers, originally published from 1819 to 1825, long since out of print and accessible only in the larger libraries, will be appreciated by all those who have had occasion to refer to such literature, and have been unable to find access to it. The following papers are republished, word for word, line for line, and page for page, as written and punctuated by the original author:

1 and 2. "Observations on some species of zoöphites, shells, etc., principally fossil. *Am. Jour. Sci.*, 1st ser., Vols. I and II (1819–1820).

3. "Fossil shells found in a shell mass from Anastasia Island." *Jour. Acad. Nat. Sci., Phil.*, 1st ser., Vol. IV (1824).

4. "An account of some fossil shells of Maryland." *Jour. Acad. Nat. Sci. Phil.*, 1st ser., Vol. IV (1824).

5. "On two new genera and several species of Crinoidea." *Jour. Acad. Nat. Sci. Phil.*, 1st ser., Vol. IV (1825). STUART WELLER.

Eocene Deposits of the Middle Atlantic Slope in Maryland, Delaware and Virginia. By WM. BULLOCK CLARK. U. S. Geol. Sur., Bull. 141, 167 pp., 40 pls., 1896.

During the first half of the century the Tertiary formations of eastern United States were among the most carefully studied and best

known deposits of the country. However, for nearly two generations little has been done to extend our knowledge of these interesting beds. Since the brilliant work of Rogers and Conrad ceased practically nothing has been attempted in the way of keeping the information regarding these strata abreast of the times. It is, then, with peculiar pleasure that the recent revival of interest in these formations is noted; and none of the late contributions is more welcome than the one just issued, on the Eocene of the Middle Atlantic region.

The memoir contains a complete review of the literature and results of past observations in this field. The author exhaustively investigates both the stratigraphy and the fauna of this important member of the coastal plain series. He traces the limits of the formation from its most northern occurrence in Delaware across Maryland into Virginia, where it gradually becomes buried beneath later formations.

A detailed study of the 300 feet of Eocene deposits in the central portion of the district shows two distinct faunas, which are named the Aquia Creek and the Woodstock faunas, the former occupying a sequence of beds extending some 60 feet from the base of the formation, while the latter apparently does not reach quite to its upper limits. The Aquia Creek stage, which contains an assemblage of forms closely allied to the middle Lignitic, probably stands, with its underlying poorly fossiliferous zone, as an equivalent, in a broad way, of the whole of the Lignitic of the Gulf; while the Woodstock stage, which contains a group of forms closely allied to the *Ostrea sellæformis* zone of the Claiborne, stands, with the overlying and underlying beds, as the equivalent, in a broad way, of the Buhrstone and Claiborne, yet it is not assumed that the lower and upper beds are exactly synchronous with the lowest portions of the Lignitic and the highest portions of the Claiborne. The much slower accumulation of the Atlantic coast materials is shown in the fact that in Alabama more than 600 feet of deposits are found between the two fossiliferous horizons above cited, while in Maryland and Virginia a thickness of but little over 100 feet is found, and without the differentiation into the fossiliferous zones which characterizes the Gulf area. The middle Atlantic Slope Eocene, therefore, represents, according to the author, only the Lignitic, Buhrstone, and Claiborne of the Alabama geologists.

These results, together with others lately obtained in a study of the Cretaceous strata throw much light upon the character of sedimentation

along the Atlantic coast during the late Mesozoic and early Cretaceous time.

Regarding the criteria of correlation which were followed the author significantly remarks:

"As the different methods of correlation are examined in retrospect, the interdependence which exists between the various classes of physical and biological criteria becomes clearly manifest.

"The faunal and floral characteristics of a formation find their full interpretation only as the physical factors are clearly understood, since the geological and geographical range of forms is determined to a large extent by conditions of sedimentation. The physical characters of a formation therefore bear a close relationship to its contained fossils, and cannot be ignored in the correlation of the deposits.

"Although the most trustworthy correlations are based upon palæontological data, the possibilities of variation in the succession of organic forms, in two distant areas, are so great that detailed correlations can seldom be satisfactorily attempted, even where general equivalence is recognized.

"The geologist, therefore, must take into consideration both the geological and the palæontological criteria in the correlation of the sedimentary rocks. No class of facts can be ignored."

CHARLES R. KEYES.

The Elevated Reef of Florida. By ALEXANDER AGASSIZ. *With Notes on the Geology of Southern Florida.* By LEON S. GRISWOLD. Bull. Mus. Comp. Zoöl., Vol. XXXVIII, No. 2 (pp. 29–62, 26 plates).

The work upon which this double paper is based consists of a trip made by Mr. Agassiz somewhat over two years ago, and one made by Mr. Griswold early in 1896. The purpose of the latter was to clear up if possible, some of the obscurity which surrounds the geology of the Everglades. The paper opens up much that is new in the story of the organic portion of the peninsula; and it is to be regretted that low water prevented Mr. Griswold from reaching Long Key, which was one of the most important goals.

The reef has been elevated from six to twenty feet, the amount decreasing southward. At Key West the coastal plain is found at a depth of 50 feet (Pliocene), while Eocene strata are 700 feet from the

surface. At Key Largo the reef has "a probable width of at least nine miles from the outer reef patches." Very great weight is given to solutional action. Not only are the Everglades in great measure explained by it, but the sounds and mud flats between the line of keys and the mainland. The disconnection is increasingly great southward, until between Key West and Cape Sable the mud flats and mangrove islands "are all that give evidence of the former continuity of the land." Thus Florida is constantly losing territory, instead of gaining it, as the older views maintained. The Marquesas, formerly considered an atoll built upon a raising bank, are, according to the author, merely a very perfect sound, and the "lagoon" is an area of greater solution. Mr. Griswold, however, does not carry the solutional theory to the extent to which it is borne by the senior author.

In many places on the keys the elevated reef is capped by an oölite. Mr. Agassiz states positively its æolian origin; but Mr. Griswold, who was last on the ground, says that, for several reasons, which he enumerates, "the topography favors an origin for the limestone in water." This guarded statement does not seem too strong for the evidence presented. This oölite was traced by Mr. Griswold much farther into the Everglades than any geologist has penetrated heretofore. Mr. Agassiz interprets the formation as modified dune sand, obtained from the beaches of the elevated reef, and blown inland by prevailing east winds. J. EDMUND WOODMAN.

Correlation of Erie-Huron Beaches with Outlets and Moraines in Southeastern Michigan. By F. B. TAYLOR. Bull. Geol. Soc. America, Vol. VIII, pp. 31–58, with map.

In this paper there is given an account of observations in a region hitherto little studied but containing evidences of a most interesting glacial and postglacial history. As stated in the title, the paper deals with features observed in southeastern Michigan chiefly in the northward projecting portion between Saginaw Bay and the lower end of Lake Huron, commonly called the "Thumb." Having spent two months during the past season in geological investigations in this region the reviewer is prepared to lend corroborative evidence as to the general conclusions of the paper and to testify to the scientific acumen displayed in the interpretation of the phenomena observed. The paper constitutes the first published account of detailed observa-

tions of glacial phenomena in this portion of the state. Almost the entire region is heavily covered with glacial drift. Very few outcrops of country rock occur. All the moraines of the region show two distinct phases. Above a contour of approximately 200 feet, which marks the upper limit of submergence, they have an irregular rolling surface, while below this line they lose their irregular features and are in fact so subdued as often to be distinguished with difficulty from the ground moraine. These water-laid moraines, however, are distinct though faint topographic features and mark the former position of the ice front as surely as the hilly land laid form.

In the paper cited a description is given of all the different moraines and beaches formed in this part of the state though the chief interest centers in those found in Sanilac and adjoining counties. In the vicinity of Imlay City a channel occupied by a swamp and bounded by beach lines was discovered extending north and west past this place and North Branch, then southwestward toward Flint. This, called the Imlay Outlet, is regarded as the outlet of a lake (unnamed) at the time the ice foot rested on its northern side. The position of the ice front is marked by a rugged moraine — the Toledo moraine.

On the retreat of the ice from this position there was next formed the Detroit moraine which, except for a tract near Yale is nearly all water laid. North of Yale near Melvin it is represented by kames and kame moraines. In this area which the author of the paper did not examine we have observed a well-marked series of kame ridges marking the northernmost limit of the eastern limb of the Detroit moraine. Northward the land fades away into the great swamp which extends north from Capac past Valley Center and Brown City to Shabona Post Office and into the almost imperceptible divide between this and the Black River swamp toward the east.

The last moraine is the Port Huron Saginaw moraine which extends from a point six or eight miles northwest of Port Huron along the east side of Black River to Tyre, thence curving around toward the southwest to Vasser. From the 200 feet contour, around the northern and eastern side of this moraine, the land slopes evenly away toward the present shore. West of the eastern limb of this moraine lies the great Black River swamp.

As the ice front retreated over this swamp region to its last halting stage at the Port Huron-Saginaw moraine, the water from the wasting glacier evidently found its way westward along the ice front, the posi-

tion of several of these outlets being noted. The last of these, the Ubly channel, was the most important. The position of this channel is now marked by the north branch of Cass River, a small stream flowing in a wide valley filled with valley gravels. At Tyre, a branch was received from the southeast. The relation of a great ice dam and the outlet of the waters is here admirably shown. The evidence of reversed drainage in the case of Black River is unmistakable. Previous to the opening of the Ubly channel when the ice-front was on the south side of the north branch of Cass River the outlet which Taylor calls the Cumber spillway was close along its edge. This position is now marked by a long narrow swamp extending from the valley of the Freiburger channel north of Cumber, parallel with the North Branch, southwest across the South Branch of Cass River and on toward Deford. In this swamp is the famous "stone wall" consisting of a low embankment of earth and bowlders extending for a considerable distance parallel with the edge of the swamp. Locally it is regarded as the work of pre-historic man. The "wall" is about eighteen inches high and was until recently obscured by vegetable mold. It was exposed by fires in clearing the swamp. Mr. Taylor refers to its resemblance to ice beaches but regards the explanation as unsatisfactory. We spent some time in this vicinity and from a study of the surroundings were convinced that the ice-beach theory is an adequate and the only adequate explanation of the phenomena. It is of interest as constituting the only instance known to us of a bowlder wall formed by ice-push in a lake now wholly extinct.

Our own observations on the beach lines of Sanilac county shows a marked northward elevation corresponding to previous observations in the lake region, the result probably of resilience following the withdrawal of the ice and to which was evidently due the reversal of the Black River drainage. This river now flows south and then east into the Saint Clair River at Port Huron. An indication of reversed drainage is seen in the direction of the branches of Black River as, for example, that of Elk Creek which rises in the southwest part of Sanilac county and flows northeast to its junction with Black River which here flows nearly due south.

While Mr. Taylor has carefully described all the glacial features observed by him, and also by G. K. Gilbert who accompanied him on a part of the trip, he has described no eskers. A well-marked example occurs about ten miles northeast of Marlette. It consists of a well-

marked gravel ridge (or "hogback") extending for several miles in a westward direction bearing to the north from the southeast corner of Lamotte township. This was evidently formed at the time the ice front rested on the Detroit moraine. Other interesting features not observed by Mr. Taylor, though suggested by him, are the well-marked kame deposits in the southern part of Sanilac county. In the vicinity of Melvin and Peck they consist of hills and ridges of gravel and sand thirty to fifty feet in height.

The name Erie-Huron is offered for the whole series of lakes represented by all the beaches, while Lake Warren is restricted to one of the separate lakes which most closely corresponds to the original idea of Spencer who proposed the name. Taylor concludes that if the relations of the moraine and beaches have been correctly interpreted then he has found outlets for three and possibly four stages, and these so related to the topography of the region and to the moraines that in at least three cases there is no reasonable doubt as to the contemporary place of the ice front. The continental ice-sheet was obviously the great dam that held all these waters up.

While testifying to the general excellence of the paper we find ourselves unable to follow the author in the degree of confidence he seems to repose in his barometer. As the correlation of some of the beach lines depends upon the identification of beaches having a vertical interval of twenty to forty feet only, and several miles apart and was made by means of a common aneroid barometer, it must be said that the conclusions in some cases are not without an element of doubt. Thus, for example, the Belmore beach is identified near Applegate at an elevation of 770 feet. Forrest Beach six or seven miles east of this has an elevation of about 735 or 740 feet. Near Cass City Mr. Taylor identifies the Du Plain beach which he says is twenty to thirty feet above the Forrest beach. The Belmore and Du Plain though so nearly related are regarded by Mr. Taylor as distinct, while between them he postulates still another stage represented by the Arkona beach which is said to have an elevation of 755 feet northeast of Spring Hill. Allowing for northward rise this beach would have about the elevation given the Belmore beach near Applegate. The question then arises which beach does the Applegate beach represent, the Belmore, Arkona or Du Plain, and what is the actual relation of these to the Forrest beach? Beaches twenty to forty feet above the Forrest beach have been identified with each of these. Our own

barometer readings westward from Croswell gave 765 feet for the altitude of a shore line stated by Mr. Taylor to be 780 feet above sea level. In an area so little diversified, more exact measurements are needed to settle some of the questions raised. Notwithstanding these questions, however, we regard the paper as an important contribution to the literature of the glacial recession. C. H. GORDON.

Elementary Geology. RALPH S. TARR, B.S., F.G.S.A. The Macmillan Company, 1897. Pp. xx+499. $1.40.

This is the most attractive elementary text-book on geology which the writer has seen. The style is generally simple, the illustrations numerous, well selected, and with but few exceptions clearly reproduced, and the mechanical execution, including the binding, is unsurpassed. The wealth of illustration is shown by the twenty-four full page plates and 268 figures, which adorn its pages. This work differs from most other text-books on geology in the greater stress laid upon the dynamic aspect of the subject. The stratigraphic and historic phases are treated briefly and concisely in 100 pages as against 275 pages given to the dynamic and 92 to the structural side. The development of life during the various periods is outlined, but no attempt has been made to teach palæontology, or to give long lists of fossils. The chapter on the life development precedes the chapter on the evolution of the land and the geography of the different periods. This departure from the more common custom of considering first the geography and then the life of each period will perhaps find favor with some teachers but not with all. Whatever be the success of this arrangement, there can be but little doubt but that the author has done well to lay the greater stress upon the dynamic phases of the subject in a book meant for high-school pupils.

In judging this book due regard must be had for the author's purpose, *i. e.*, to "furnish a companion and adjunct" to his *Physical Geography*. It is his hope that the two books will be used together, the geology being taken after a study of the air and ocean, and before the physiography. Knowing the author's purpose, the omission of some topics, such as "river cycles" and "base levels" can be understood, since they have been treated in the *Physical Geography*. In spite, however, of some omissions, there is considerable repetition in the two books—something hardly to be avoided. The *Geology* is a more ele-

mentary book than the *Geography*, whereas the present practice in high schools, one recommended by the Conference on Geography appointed by the Committee of Ten, is to place physical geography in the earlier part of the curriculum and geology, when studied at all, near the end. For these reasons, and because of the size of the two books, it is questionable whether they will ever be widely used together. Where such use is attempted, considerable culling and dovetailing will be necessary. This would be easier for the teacher if the paragraphs were numbered. But doubt as to the feasibility of the author's plan does not mean condemnation of the book as a whole. It is admirably adapted for high-school pupils, and it is to be hoped that it will be widely used.

There is so much that is to be commended in it that it is to be regretted that a few slips have passed uncorrected. On page 118 the language implies that the term "oxidation" embraces all the chemical changes caused by percolating water; and the expression "limy shells" (p. 132) as applied to corals is hardly accurate. The statements in the text concerning normal and reversed faults (pp. 293, 324) do not correspond with the diagrams (p. 292) and the following sentence, "Mountains are present in nearly all parts of the world" (p. 314) does not agree well with another statement that "the formation of mountains occurs in only a few comparatively small parts of the whole earth" (p. 328). It may seem hypercritical to refer to some of these points, but too much care cannot be taken in a text-book to be used by immature pupils, and perhaps by teachers, who have not a wide knowledge of the subject. But these are not vital and do not detract greatly from the value of the book. Professor Tarr can be congratulated upon the degree of merit to which the book has attained.

LEWIS INSTITUTE. HENRY B. KÜMMEL.

ABSTRACTS.

The Solution of Silica under Atmospheric Conditions. By C. WILLARD HAYES.

While it is well known that under conditions prevailing at considerable distances below the earth's surface silica is one of the more easily soluble substances entering into the composition of the earth's crust, it is commonly regarded as the mineral least liable to be affected by solvents under ordinary atmospheric conditions. Some recent observations, however, show that even quartz pebbles are not proof against chemical as well as mechanical erosion. At several widely separated points in West Virginia and Tennessee occur coarse conglomerates, in two cases Carboniferous and a third Cambrian in age, in which the projecting portions of the pebbles have been deeply etched, evidently by solution. The pebbles vary in size up to an inch in diameter and are composed chiefly of vein quartz and quartzite together with a few of chert and feldspar, embedded in a coarse sandstone matrix. The projecting portions of these pebbles, particularly those composed of quartz and quartzite, are deeply pitted with rough, irregular surfaces, in many cases as much as a third of the pebble having been removed. From the form assumed by most of the pebbles, it would seem that their interior was more easily soluble than the outer portions. The latter usually forms a sharp rim within which is a depression with a slight elevation at the center. The etching is not confined to the larger pebbles, for on closely examining the surface of the matrix it is seen that in many places the projecting portions of the sand grains have been removed, leaving a more or less smooth mosaic. A comparison of these etched pebbles with the glyptoliths or facetted pebbles described by Woodworth and others shows clearly that they are not produced by the same agency as the latter, namely wind-driven sand. Everything, on the other hand, points clearly to solution.

Again, numerous geodes from the Carboniferous limestone in Tennessee, collected by Campbell and Taff, show etching similar to

that described above. They vary from three inches to a foot in diameter and beneath the rugose opaque surface are colorless and translucent, resembling in texture extremely fine-grained quartzite or slightly granular vein quartz. Under the microscope this is seen to be made up of spherulitic aggregates of quartz grains with much coarse granular quartz but no cryptocrystalline or amorphous silica could be detected. Many of these geodes are deeply etched upon one or both sides, not only the opaque shell being removed but also portions of the translucent interior. From its microscopic character, the silica of which they are composed would appear to be but little more liable to solution than vein quartz or quartzite. Minute quantities of amorphous silica may, however, be present and by their solution facilitate the removal of the crystalline grains by solution or otherwise. Hence less importance is attached to the solution of these geodes than to the etching of the conglomerate pebbles.

The wide separation of the localities at which these cases of the undoubted solution of silica occur, renders it improbable that they are due to some peculiar and exceptional conditions, such as the presence of thermal, alkaline waters. It seems rather that they must be attributed to the action of widespread agencies working in these cases under more than ordinarily favorable conditions so that the effect is exceptionally striking. All the cases occur in a heavily forested region where there is a thick layer of humus and doubtless an abundant supply of the humus acids. Further, the region is one in which forest fires are frequent and considerable potassium carbonate must be supplied to surface waters by leaching of the resulting ashes. The conditions, therefore would appear to be favorable for a chemical process somewhat as follows: By the oxidation of the vegetable tissues in the process of decay, the humus acids are formed, chiefly humic and crenic. These absorb varying quantities of free nitrogen from the air forming the azo-humic acids, which, in turn, combine with free silica. The resulting acids combine with alkaline carbonates, particularly potassium carbonate, to form easily soluble salts. In most cases the etched surfaces of the pebbles described above support a more or less abundant growth of cryptogamic vegetation which might facilitate the solution in two ways: first by supplying humus acids directly from its own decay, and, second, by absorbing solutions of those acids from other sources and keeping the rock surfaces moist so that their solvent action might be practically continuous.

While it is readily granted that such agents seem inadequate to produce the effects observed, no others at all comparable with them in efficiency suggest themselves. And if the above conclusion is correct, a solvent capable of removing a third of a quartz pebble an inch in diameter, while still imbedded in its matrix, must be an extremely important factor in gradation when acting under the much more favorable conditions prevailing in the humus layer itself where the surface exposed by the quartz grains is vastly greater in proportion to their bulk and where the solvent action is not interrupted as it must be on exposed rock surfaces.

The Crystalline and Metamorphic Rocks of Northwest Georgia. By C. WILLARD HAYES and ALFRED H. BROOKS.

The region discussed in the paper extends southward 100 miles from the Tennessee line and westward twenty to eighty miles from the Atlanta meridian. It embraces about 4000 square miles, forming a belt to the east and south of the Georgia-Alabama Palæozoic area. The rocks of this region naturally fall into three groups: (1) the granites, gneisses and crystalline schists of the basal complex — probably Archean; (2) the slates and conglomerates of the Ocoee series — probably Algonkian; (3) intrusives in the other two series.

The first group includes the Acworth gneiss, Austell granitoid gneiss, Corbin granite and the Piedmont gneiss and crystalline schist. In the second or clastic group only four members are distinguished and formation names have not yet been assigned to them since this classification is not regarded as final. These four members are (*a*) basal conglomerate resting on the Corbin granite; (*b*) black slate often graphitic; (*c*) a series of interbedded slates and felspathic sandstones; (*d*) garnetiferous slate probably an altered phase of (*b*) and (*c*). The intrusives, which are found in association with members of both the other groups, but most abundantly in a belt from ten to twenty miles broad along their contact, named in the order of their intrusion, are (*a*) amphibolite schists and diorite; (*b*) gabbro and basic greenstone schist; and (*c*) Villa Rica granite and associated coarse pegmatites.

The above classification as well as the map accompanying the paper is to be regarded as only preliminary since the necessary petrographic study of the rocks has not yet been completed. The region discussed is embraced within the limits of the Dalton, Cartersville, Marietta,

Tallapoosa, and Anniston folios of the United States Geological Survey which are now in course of preparation.

The Age of the White Limestone of Sussex County, New Jersey. J. E. WOLFF and ALFRED H. BROOKS.

The principal new observations contributed to this well-known field by the authors were those indicating the presence of several longitudinal faults along the boundaries between the Cambrian limestone and sandstone and the white limestone and associated crystalline rocks; and the discovery, at a new quarry in Franklin, of a crevice in the white limestone which has been filled up by the overlying Cambrian arkose, which contains bowlders and fragments of the white limestone, and fragments of mica, feldspar and other minerals characteristic of the white limestone or associated rocks. From this and other localities, they conclude that the Cambrian sandstone contains the débris of the white limestone granite and associated rocks and explain the apparent transition between the blue (Cambrian) and white limestones as due to fault brecciation and shearing, and the apparent interbedding of the white limestone and quartzite as due to the deposition of the latter on the irregular surface of the white limestone, with local faulting in some places. They conclude that the white limestone is of pre-Cambrian age and an integral part of the gneissic formation. This paper will appear in full in the 18th Annual Report of the Director of the United States Geological Survey.

Erosion at Baselevel. By M. R. CAMPBELL.

Some late observations by Mr. C. W. Hayes and the writer on the solubility of quartz under atmospheric conditions and the writer's own study of local baselevels in the Appalachian coal field seem to throw some light on the question of the ultimate result of undisturbed erosion, a result which has hitherto received but little attention from physiographers.

The conditions which seem to facilitate the solution of quartz are those which would probably prevail during the final stages of the process of baseleveling to a much greater extent than under ordinary conditions of erosion; consequently it seems probable that most, if not all, of the waste of the rocks which is washed in from the surrounding

slopes is removed by solution and does not accumulate on the surface of the plain.

This conclusion is still further substantiated by the fact that in the local basins observed in the coal field, the surrounding slopes are sharply separated from the bottoms of the basins, showing that even in these small examples there is some action going on by which the waste is carried off in solution leaving the floor of the basin unobstructed and a nearly perfect plain.

If these conclusions are correct, the baseleveling epochs of the past may have been marked by very completely formed plains, and the slopes of the unreduced areas may have been sharply separated from, instead of blending with, the surface of the plain.

Origin of Certain Topographic Forms. By M. R. CAMPBELL.

The recognition of apparently abnormal physiographic forms in limited areas has induced the writer to undertake an investigation of their probable cause. Since the abnormal types are limited in their geographical distribution, they are doubtless caused by local variations in some of the conditions governing erosion. Climate and rock character are variable, but changes in them could not produce the forms in question. Declivity must be accountable. Declivity may be changed by crustal movements, but those which operate over a broad area change the declivity as a whole, and hence cannot produce local variation. Movements which are limited in their extent are the ones which must be looked to for local variation and the production of abnormal forms. Local uplifts may result in the production of normal faults, monoclinal folds, symmetrical folds, and dome-shaped uplifts; each of these structural forms, when produced during the final stage of an erosion cycle,—for at that time alone will they introduce new erosion conditions,—will be marked by physiographic features peculiar to itself.

The production of a scarp from a monoclinal fold is perhaps the most remarkable form, and it is due to a peculiar combination of slow, regular uplift, homogeneous rocks, and baseleveling conditions outside of the area affected by the uplift.

This principle is applied to the solution of the Blue Ridge scarp in North Carolina, and it is shown that the physical features of that region could have been produced by a monoclinal uplift in a broad

peneplain. On this supposition the Blue Ridge plateau was once continuous with the Piedmont plain, but the latter remained at sea level while the former was slowly elevated 2000 feet. There were halts in this movement, during which partial peneplains were formed on the western side of Blue Ridge. The final result of such a combination of crustal movements and periods of baseleveling is that all of the peneplains on the western side of the Blue Ridge, collectively, represent approximately the same time interval as that represented on the eastern side by the Piedmont plain.

This theory also explains the present condition of the New River-Roanoke divide, and why the former stream has not been captured by the latter,—a crucial test for all theories relating to the origin of this scarp.

The same explanation is also suggested for the Black Hills of South Dakota,—a dome-shaped uplift in which the outer rim of Dakota sandstone is in the zone of maximum erosion, and consequently is kept at baselevel, while the inner belt of limestone owing to its more rapid upward movement is unreduced. This is offered merely as a suggestion to geologists in the hopes that it will be entertained as a working hypothesis and its applicability tested by persons familiar with the field.

Dikes in Appalachian Virginia. By N. H. DARTON.

An account was given of further discoveries of diabase dikes and of certain dikes of acidic eruptives among the Palæozoic rocks near Monterey in Highland county, Virginia. The diabase dikes are similar to those described by Messrs. Diller and Darton some years ago, but the acidic rocks are very great novelties for this region. The rock is porphyritic diorite containing quartz, mainly in rounded grains, with plagioclase, biotite, and hornblende phenocrysts, in a white groundmass. The dikes are of small extent and appear to be restricted to a limited territory. The area is one in which the most prominent anticline of central Appalachian Virginia reaches its culmination.

The abstracts in this and the previous issue of this JOURNAL were read before the Washington Meeting of the Geological Society of America.